ESCOLA POLITÉCNICA DA UNIVERSIDADE DE SÃO PAULO
DEPARTAMENTO DE ENGENHARIA DE CONSTRUÇÃO CIVIL

CIB W99
International Conference on Construction Project Management Systems: The Challenge of Integration

São Paulo 25-28 March 2003

CIB W 99 – Quality and Safety on Construction Sites

This CIB W99 Conference

This Conference of W99 - Quality and Safety on Construction Sites is expected to be a great opportunity to develop the concepts related to construction management systems interfaces and the integration of environment, quality and occupational safety and health together with project controls. It follows previous discussions in CIB Conferences held in different countries in the world in recent years.

After the dissemination of quality management and quality improvement in construction and the increase in occupational safety and health and environmental requirements, the integration of all these elements, together with cost and time, seems to be a significant challenge in the near future. The central idea of the Conference will be to examine the importance of coherence among players individual systems and needs in integrated actions in project management. However, it is of paramount importance to highlight that it is not a "formal integration" that is searched, but a real "agreement" and commitment among construction project players, which involves the co-ordination of project-specific arrangements, design review and validation, risk analysis and strategic decision taking, communication and planning, related to quality, occupational safety and health and environmental issues. Thus, integration systems also concern the understanding and improvement of co-operation mechanisms that can be identified as key factors of successful management practices.

Moreover, as construction projects are always specific, even if each player has a management system implemented, the whole project management is not assured under a viewpoint of quality, safety and environmental patterns. Some recently issued or expected changes concerning quality management standards and occupational safety and health legislation and standards are stimulating this discussion.

Last but not least, national contexts are factors which influence construction. Thus, the professional relationship and cultural specific factors such as contracting systems, standards and legislation were also chosen as relevant themes in the program of the conference.

Experts from a number of different countries are expected to attend this International Conference, and therefore it is the right arena for discussing and updating these issues. It will provide an opportunity to display the current practices in each subtopic area, highlight country practices, and to measure global activities in quality.

What is CIB W99

CIB - International Council for Research and Innovation in Building and Construction

The International Council for Research and Innovation in Building and Construction Research (CIB) was established in 1953 to foster international collaboration and information exchange among institutions engaged in research with the building and construction sector. CIB consists of more than 50 commissions and task groups whose individual missions are focused on initiating research projects, organising meetings, and organising international symposia and conferences.

The Working Commission W99 was created in 1995 under the name of "Safety and Health on Construction Sites" and recently renamed to "Quality and Safety on Construction Sites". It is committed to the advancement of the safety and health of construction workers and to the improvement of quality in construction. The tools necessary to accomplish this end include designing, preplanning, training, management commitment and the development of a sound quality and health and safety culture. With an emphasis on research and innovation, it is a priority of the W99 Working Commission to challenge construction and design professionals to fully embrace safety and health on job sites throughout the world.

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CIB W99
Quality and Safety on Construction Sites

INTERNATIONAL CONFERENCE IN SÃO PAULO, BRAZIL

CONSTRUCTION PROJECT MANAGEMENT SYSTEMS:

THE CHALLENGE OF INTEGRATION

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CIB W99

Quality and Safety on Construction Sites

INTERNATIONAL CONFERENCE IN SÃO PAULO, BRAZIL

CONSTRUCTION PROJECT MANAGEMENT SYSTEMS: THE CHALLENGE OF INTEGRATION

25-28 MARCH 2003

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SPECIAL PAPER ON INTEGRATED MANAGEMENT SYSTEMS

Integrated Management Systems in Construction (IMSinCONS)
Luís Alves Dias

KEYNOTE SPEECHS

Occupational safety and health management systems in the construction industry (OSH–MS): the ILO approach
Alberto López-Valcárcel

The evolution of the management systems in construction
Odd Sjøholt

Occupational safety and health management systems in the construction industry (OSH–MS): the ILO approach.

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Abstract

The problems and challenges that construction safety continues to face are still huge. According to SafeWork estimates, every year a minimum of 55,000 fatalities occur at construction sites all over the world.

It has long been recognised that the continuous moving of the workplace (the construction site) calls for a specific approach to occupational safety and health (OSH) management at construction sites, in which planning, co-ordination and budgeting become extremely important.

On the other hand, the idea that the client and the designer should also play an important role in the planning and co-ordination of OSH for the construction site has also attracted a lot of attention lately. ILO Code of Practice Safety and Health in Construction, 1992, gives wide coverage to these issues.

However, the centre of attention in the field of OSH management in construction has now moved towards a more dynamic and systematic approach, in line with international quality and environment management standards.

The basic idea of this new approach, namely the OSH management systems, is that of continuous improvement in OSH performance. In this sense, OSH management at the enterprise level should not only be considered as a means for the observation of relevant legal obligations, but it should also be aimed at achieving the best OSH performance.

It was in this context, that the International Labour Organisation (ILO) recently adopted its Guidelines on occupational safety and health management systems (ILO-OSH 2001), at a tripartite meeting of experts that took place in Geneva in April 2001.

ILO-OSH 2001 provides a unique international model, compatible with other management system standards and guides. It is not legally binding and not intended to replace national laws, regulations and accepted standards. It reflects ILO values such as tripartism and relevant ILO international standards.

At the enterprise level, the ILO Guidelines encourage the integration of OSH-MS with other management systems and state that OSH should be an integral part of business management. While integration is desirable, flexible arrangements are required depending on the size and type of operation. Ensuring good OSH performance is more important than the formality of integration. As well as this, ILO-OSH 2001 emphasises that OSH should be a line management responsibility.

At the national level, the ILO Guidelines provide for the establishment of a national framework for the OSH-MS, preferably supported by national laws and regulations. At the national level they also give countries the possibility of developing “tailored” guidelines to address the specific conditions and needs of enterprises or organisations, or groups of companies, taking into consideration their size and the type and degree of risks.

The ILO Guidelines are currently available in more than 10 languages, and have already had a significant impact on OSH-MS national policies, guidelines and standards, worldwide.

The evolution of the management systems in construction

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Abstract

Scientific management has its base from early 1900, mainly with roots in US. Adaptation in the construction industry started after World War II, in the 1950ies. The building and construction process itself forms an integral part of the management systems, and the development have undergone a number of phases. First focus was on the construction processes on site. Work-studies gave data to minimise the use of materials and manpower. Manual scheduling and control means were developed for use on construction sites. The design process came in focus in the mid 1960ies, with elements of functional requirements and performance concept. Computerised network planning programmes came on market, resulting in confuse instead of focus on the building process. More important was attempts to bridge design and construction work. New procurement models were developed since 1970ies, regrettably much to getting a larger financial control and profit possibilities. Developers of various kinds entered the market. Total productivity seemed not to improve, and budgets were too often overrun. To and from since 1970ies is focused on Safety and Health for construction workers, mostly driven by regulations. Quality came up as a new external driving force in the mid 1980ies, resulting in documented quality systems. This has been the most dramatic event in the history of management systems. A more global concern is since 1990ies a focus on environment and sustainability. Regulations are the driving force, but the requirements are little quantifiable. The construction industry will need time to adapt.

The future structural changes in construction may lead to more total services for facilities, contracting, supply, and distribution of materials and collection of waste. The evolution of management will mainly concentrate on integration of the various aspects into overall systems for projects as well as for companies. One main target is to really bridge and integrate design and production. It is anticipated that the next generations of ICT will give technical support for integrated management tools. The crucial point will be to create a simplicity that can be managed by people, hopefully improving the social cooperation and teamwork to achieve a human balance in management systems.

Keywords

Construction; company; project; organisation; management; systems; evolution.

1 Factors influencing the evolution of management systems in construction

The paper describes first how the industrial management theories came about since 1900 and was adapted into construction since 1950. Likewise is outlined how administrative tools and data based systems have been transferred to and further developed in construction. Finally the future evolution is discussed, among others the integration of QHE (Quality, Health and Environment) and the potential use of ICT (Information and Communication Technique).

The paper refers much to the author's experiences and includes some personal viewpoints, with no ambition to be academic reliable. Thanks to a number of helpful colleagues around the world the writing has been supported by updated information. Basic knowledge has been extracted from some lesson books for chapter 2 [1] and for chapter 3-4 [2, 3, 4].

"In construction" is in this paper taken as the industry's Companies as well as the Projects and even the resulting Built environment.

"*Management systems"* can be defined according to ISO 9000:2000:

- Management = coordinated activities to direct and control an organisation
- Organisation = group of people and facilities with an arrangement of responsibilities, authorities and relationships
- System = set of interrelated or interacting elements
- Management system = system to establish policy and objectives and to achieve those objectives

"Evolution" is taken as the gradual change in the characteristics over generations.

Factors influencing on evolution of CMS are complex in character and relationship. The cultural framework based on economic, social and political facets influence basically. Transfer of construction management systems between cultures may be complicated [5]. It is even hard to distinguish evolution of management from the development of technical industrialisation in construction.

The main needs and requirements to management systems are as follows:

- *The organisation's internal needs* according to policy and objectives, and how to achieve those, influenced by economy, employment, owners etc.
- *External contractual requirements* from customers, clients, contract partners, suppliers, finance institutions etc.
- *External legal requirements* from public authorities or other regulatory bodies, related to Plan and Building Act, Occupational Safety and Health act, Environmental act etc.

The development of management principles and related systems is most often a result of R&D work. Basically the focus has been on manufacturing, but several of the more sophisticated systems are created to solve military objectives. But the fundamental nature is significantly different between a permanent organisation like a company and the ad hoc building projects. Transfer to construction has been pushed by the industry's own researchers by adaptation to the industry's specific needs. Consultants are eager promote new and sometimes trendy managerial tools. But their knowledge of construction is less and the risk is greater for mismatch.

Funding of R&D in construction varies in total as well as in the parts going to rationalisation and management improvement. The earlier prioritising of topics by the universities of researchers themselves is changed. Now a government together with the industry decides the strategies and define specific programmes. Even the competition between research organisations is increasing, as tendering for projects is introduced. Cooperation seems to be easier to organise internationally than nationally. This has been successfully supported within many organisations. The CIB has played a major role concerning organisation and management since 1960ies. Regional funding is also contributing to cooperation, like the EU research programmes.

The evolution of management systems follows closely the available ICT products. The development of ICT changes the prospect of management systems. Around year 2000 all new opportunities may lead to a leap.

2 Review of the Industrial revolution and scientific management

Management in construction has its roots from manufacturing industries. But the principles need adaptation to the many explicit demanding challenges in construction. Even though, the evolution history of management in basic industries is an important background for reviewing the management in construction.

In the early years of 1900 – after a past century of industrialisation – the workplaces became an object of scientific studies. F.W. Taylor (1856-1915) in US started to focus on the productivity and payment rates documented by work-studies. This empirical and rational approach was the beginning of a scientific management era. In parallel worked the team of husband-and-wife Frank (1868-24) and Lillian (1878-1972) Gilbreth. Frank started out as an apprentice bricklayer. He noted the diversity in methods and speed used by the workers. He developed and documented the best ways, even for concrete work. He involved workers in improvement work without physical exertion.

Social theory and human relations came up even in parallel. The union-management cooperation was introduced as well as the employee participation in decision-making. Amongst others to influence came the French engineer Henry Fayol (1841-1925) with his management theory with 14 principles. Examples: Division of work, authority, discipline, unity of command etc. The German Max Weber (1864-1920) described in parallel a theory of bureaucracy. His seven essential elements were like: Clearly defined authorities and responsibilities, a hierarchy of authorities and positions, selection of members on basis of formal qualification and examinations, appointed not elected officials, strict rules for conducting their duties. Chester Barnard (born 1886) defined the nature of cooperative organisational systems. He saw a main goal in maintaining internal equilibrium whilst adjusting for external forces, including all sort of interesting parties.

Human relations were further studied, and the most publicity achieved the Hawthorne plant experiments from the mid 1920ies. Productivity raise was obtained by improving illumination – but also within a focused control group without illumination changes. This effect and the studies have been much bespoken and discussed.

Another American was Henry Gantt (1861-1919), educated as a mechanical engineer. He built on Taylors elements and wrote about the mutuality of interests between labour and management, scientific selection of workers, incentive rate to stimulate performance and detailed instruction on work. He even made graphs with horizontal bars for each worker illustrating their progress related to the task standard time. During the World War I he served the US Government in scheduling the low productivity work in navy shipyards. He came up with the *Gantt chart* concept, which was revolutionary for this period.

People and motivation was the topic for Abraham Maslow (1908-70). He defined a hierarchy of needs like a ladder where one goes from the lowest level and upwards: physiological (food), safety, love, esteem and self-actualisation. An example of a specific motivation scheme is the *Scanlon plan* late 1930ies, named after Joseph Scanlon. The plan included joint committees with union and worker representatives proposing laboursaving techniques and a *group* reward based on *reduced labour costs*.

As the technologies became more advanced the managers even had to handle a more complex environment. During and after the World War II the management scholars turned from shop-level orientation to general management theory again. An increasing number of academias were involved and practical advisors offered their service. Peter Drucker (born 1909) advocated a number of principles. In particular he is remembered for the concept *Management by objectives – MBO* (even though others had done similar earlier). Douglas McGregor (1906-64) taught psychology and experienced for some years also the position as a president of a college. He presented two *theories X and Y* to illustrate the "traditional view of direction and control" versus a "humanistic view". X stands for human's dislike of work and responsibility, so they must be directed and controlled. Y stands for human's natural interest in physical and mental efforts in work, interest in self-control to objectives to which he is committed, to accept and seek responsibility when qualified etc.

Chris Argyris (born 1923) launched a theory about the difference between managers' declared values and view on people and their leadership in practice based on hidden values (Model I). He advocated a training programme for managers to first in a group to understand their shortcomings and then to dare in own company to change it to more openness (Model II).

Rensis Likert (1903-1981) introduced a concept for participative management within an organisation. Overlapping groups complemented the traditional hierarchy and were based on commitment and consensus. Frederick Herzberg published in 1959 *The motivation to work*. He defined *motivation factors* in the job content like achievement, recognition, challenging work, responsibility and opportunities for growth. On the other hand he described preventive *hygiene factors* in the environment like supervision, interpersonal relations, physical working conditions, salaries, company policies, benefits and job security. Those factors resulted not to higher motivation, but declining under an acceptable level they led to job dissatisfaction.

N. Wiener (1894-1964) launched around 1950 the word *Cybernetics*. It was a system theory of self-control through a communications loop. Information feedback allowed learning and adjustment for future situations. For organisations it implies that information gives opportunities for communication and control. "If you cannot measure it you cannot manage it".

Industrial Democracy came up in the 1960ies. It was soon experienced that the workers representation in the boardroom had to be extended to real influence on decisions on own work. Groups were given more responsibilities for integrated tasks. F.E. Emery and E. Thorsrud at the Tavistock Institute launched the phrase *socio-technical system*. A main element is the reciprocal influence between the technical system (task, tools) and the social system (relation between people).

Finally to mention is the evolution of numerical models developed to help managers in analysing complex tasks. Mathematics and statistics have been utilised in a number of models to find “optimum” or “best way”. Walter Shewhart introduced Quality inspection based on statistics in the 1920ies. During the World War II quantitative methods were used to solve various problems. Then followed the introduction of Operation Research in production management. Examples are: proper stocking level of inventories, scheduling and controlling production, manufacturing in economical batches, quality control and capital acquisition. The modelling techniques were based on statistics, probable theory, linear programming, queuing theory and game theory. The evolution of computing aids was important in performing the calculations. It was a rather laborious work when the only tools were the slide rule and mechanical apparatus. Punched hole cards and sorters were a next step before the new era began with electronic computers.

To sum up this chapter: The industrial scientific management was created from about 1910. A number of theories and concepts were developed during the following 50 years, mainly in US, UK and some other European countries. The construction industry was so far not specifically considered.

3 Review of the past evolution of management of building projects

3.1 Early focus on rationalisation of building production – 1950

The interest for the scientific management tools in construction come up after the word war 1940-45. There was a shortage of dwellings and other buildings in many countries. The rebuilding however was difficult because of scarcity of the most needed materials, machinery and fuel. On the other side there was manpower enough – eager to get paid work. It took some years to organise and fund R&D. Then the goal was simply to find rational building methods at lowest possible costs.

The management aspect was to record and analyse site work in detail to find the most efficient production processes. From mid 1950ies came work-studies of various kinds into use on construction sites. Special sort of clocks, frequency/interval studies and then elapse photo camera were used. Later followed the modern bar-coded registration sheet with optical reading transferred to a computer and later video camera. This development of study methods covered a period of 15-20 years. The Norwegian Building Research Institute (NBI) took actively part in this R&D together with some interested main contractors. Worker unions were involved in the studies to assure that the data were not used to set wages as piece rates. In this period it was even a development on constructing a standard time system for basic movements, measured in 1/1000 seconds. The Movement Time Measurement – MTM – was explored for use in the construction industry (Sweden). But it was never realised in practice.

The studies resulted in a detailed understanding of obstacles and core rational principles as well as a reliable and valuable data bank. A technical outcome was the analysis of various building methods and use of materials, comparing at the same time with the use of manpower. It was important to base the analysis on the spending of production factors, and to leave the unity prices open for each project and the change over time. It is general known that that relatively high material costs related to low manpower costs lead to other optimum production methods than the opposite.

Planning methods were based on the process knowledge and time data of all kind of operations. Still the F. W. Taylor principles from time and motion studies in the first decade of 1900 were ruling. The goal was a production flow with a minimum of waiting times for workers and a maximum of repetitions. The Norwegian Building Research Institute (NBI) served the industry with a set of printed forms for planning and monitoring [6]. This manual system required a great deal of work; on the other side it gave the planner a rather good insight in the problems and possibilities for a rational production flow. Courses up to two weeks were arranged for production site managers from contractors, both for site studies and for the detailed work planning. But far more helpful was the establishing of clubs of contractors. The Institute was coaching them through a two years program for their establishment of their own production management system [7].

Some examples exist also on adapting numerical techniques in construction, as described in the scientific management chapter. Even though some experiments showed benefits they were mostly promoted by academias and had little root in companies' need.

The further vision was to improve production methods, plan for large series and increase prefabrication. Industrialisation was seen as the future way to increase productivity – and profitability. US government launched Operation Breakthrough in 1969, and invited 22 companies to design and build innovative dwellings on 9 sites. The goal was to establish a base for industrial manufacturing. But the result was not successful and none of the systems survived.

3.2 Management of the design process - 1960

The traditional organisation of a building project was in the 1950-60ies based on the client engaging designers and contracting contractors. Design and production were the two main phases. Use or operation including maintenance was seen as a separate topic. The focus on site rationalisation led in the 1960ies to an understanding of the need to design for smooth production. About 1965 raised the interest of systematic studies of user needs or requirements. Researchers communicated through CIB working commissions, and came up with a theoretical framework. It was both about functional requirements and the assessment of necessary properties of materials and structures in a building. Classification and coding was a part of the concept. However, this basic approach took a long time to mature and to put into practice. In between the Value Engineering concept was offered in the mid 1970ies to construction by industrial consultants. This was a quantitative tool to find optimum design. The idea was to connect cost to needed functions and assess values, but it had little practical application in construction.

A similar idea came up again around 1990, when the concept of Quality Function Deployment – QFD – was introduced in construction. A matrix is used to analyse client's functional requirements versus design features, and to use weights for priorities or importance. Experiments showed some relevance, but the calculations were time consuming and the use diminished. Life Cycle Analysis –LCA – has also been introduced as a technique, but remains most as a principle. In the beginning of the 2000 it seems as the very first design phase – user needs – again comes in focus. One final remark on the functional concept is that is has radically changed authorities regulations from prescriptions to functions, starting from about 1990. More about that is written in a later section.

The incorporation of rational production principles and other requirements into the design process is a continuing challenge. The design and decision process need to have data and to balance all sorts of requirement or wishes – weigh them together and even to search minimum cost. One problem is about what and how, as discussed above. The other problem is about the organisation of the process.

3.3 Organisation of the building process as a whole - 1970

How shall a project be organised most efficiently? A main concern is about risks, liability, cost and profit. From early 1970 there has been a continuous implementation of various organisation models for procurement. Design-build means one organisation being responsible for the total delivery. The performance requirements concept was adapted to be used in specifications. Various other ways have been used for competitions and contracts. As the building process turned to be more complex, so did also the contracts. Lawyers appeared in the business and disputes came about.

Construction Management - CM - is more or less the opposite of design/build. The client is contracting one company to coordinate the whole process and manage directly both designers and contractors by means of subcontracts. The client may even perform this concept on his own.

The development trend has been that contractors have searched for models that could position them direct to the client from the early beginning of a project. Teambuilding and partnering was launched to instigate cooperation between client and project members, though without essential contractual implications. A contract could also be negotiated without competition, may be with rules for sharing of savings.

In parallel the structure and business character of the industry is changing. General contractors have from the 1980ies reduced labour forces and use instead subcontractors and specialist enterprises. Designers are employed or hired by contractors. Family and private owners of companies sell to investors – financing business units. The new sorts of contractors or developers invest in land as well as in past industrial areas and construct for the open market. They can even offer financing to the clients. The local markets have extended to global markets including international cooperation. This has in the 1990ies opened for the concept Build-Operate-Transfer – BOT –as a way of reducing governmental investment. Consortiums take all responsibility even for financing. This is another indication of the rapidly growing influence of finance business units in the construction sector. This means an even stronger focus on return on investment and profit margins. The continuity of the owner as the top manager is outdated since the 1990ies. Instead there may be a new sort of leadership and more turbulent internal organisation with more often changes of strategies. It can be questioned if this again means less continuity and investment in improvement of construction project management systems?

3.4 Introduction of computers for network planning and project management

Computers were within reach in many countries around 1960, though most in service centres. For management systems this resulted in programs for planning according to the network principles. The Critical Path Method – CPM – was launched in 1957 as a computerised arrow diagram, allowing finding critical activities and total time. Next followed a network based on three time estimates for each activity, pessimistic, most probable and optimistic. The calculation was based on statistical probability theory. This method was called Program Evaluation Review Technique – PERT. US Navy used PERT in managing the development of Polaris missile.

In short time in the mid 1960ies this new management tool was introduced in the construction industry. The vision was to make master plans for all projects – and to really be able to control in a much better way than before. Planning consultants were hired to make the plans, as they were linked to computer centres. They were in general little familiar with the construction process, and based the planning on interviews. It took some time to get the calculation and the result back. And worst of all, the first versions were difficult to understand, mostly listing with tables and complicated networks. In addition is the nature of a building project difficult to transform into a network of this conventional first version. So my understanding of this attempt is that it did not fulfil the expectations and even delayed further improvements of management systems.

NBI was also an actor in the network childhood with a version based on manual management system principles. The line balancing and workers team flow was a part of it. Further on the training effect was incorporated, which means a longer unit time during the first start period. For companies it was rather awkward to have the data sent by post to us. Then followed punching of holes in cards and to bring them to a computer centre. Finally the result was sent by post back to the contractor. This modified network pack was developed much too early, as the computer facilities were not ripe in the 1970ies.

Another effect of the assumed fast growing computer facilities was a vision of a new generation of building process control using databases for a generic process flow and project modelling. UK was in the forefront in 1970, and had spent 20 man-years over a short period. Hundreds of building process flow charts were presented, and even translated into Norwegian. It gave a raise to understanding of the elements of the process, but did not result in practical solutions. It gave a rise to data based management information systems and expert systems during the 1980ies. This became really a topic for researchers, but again with less practical use.

3.5 The second generation of ICT tools for management of construction

The development from computer centres in 1960ies up till today's hardware is like a revolution. The construction industry has (with some time lag) followed the stages from stationary company computers to personal computers, then portable computers and even handheld computers (palm). The use of pencil changed slightly from 1985, experiencing the efficiency of text writing, calculation, diagrams and illustrations. The communication evolved in parallel from phones to fax in the 1980ies. Data were transmitted by diskettes. The computer connection via telephone cable net and local wiring opened for directly transmittance around 1990. From 1995 the Internet was launched and gradually improved to serve for email, websites, information retrieval, trade, project communication etc.

The improvements have all the time been followed by new software developed for the open market. The evolution of management programmes and tools in the 1990ies resulted in a second generation. Planning tools (MS Project) and CAD design programmes (AUTOCAD) were considerably improved. Communication ways changed to wired network between computers and next via Internet. But the necessary adaptations to construction processes took long time, mainly due to the small and fragmented market.

Materials flow has been much concerned in management of construction. In the late 1980ies there were proposals to transfer methods from manufacturing and trade businesses (Sweden 1987), resulting in a few development projects. In Japan the *Just In Time – JIT* – concept was demonstrated by Toyota in a successful manner. I the mid

1990ies some studies was performed on materials administration and logistics for building sites (Denmark, Norway). At the same time the structure amongst wholesalers changed to larger groups of retailers. They invested in computerising of stocks and deliveries, which fit very well to the rising interest from contractors in logistics. The *Supply Chain* became a motto, even leading to partnering as a lasting cooperation between suppliers and buyers. Material need and delivery was integrated in the scheduling (MC Project) and automatically monitored. Materials ordering in the 1980 from the catalogues with barcodes and optical readers moved over to Internet in the late 1990ies. Orders and payment became online between the supplier, buyer and the bank.

In Japan the large general contractors were leading the development, offering design and build. A sort of partnering was the culture since long, including subcontractors. The contractors had own research institutes with 2-300 researchers (Takenaka). One example of development work concerns logistics for a specific site in Tokyo 1999 (Shimizu). A computerised schedule showed the actual needs of deliveries for all trades. The manufacturers were connected thorough a project information sharing server. The carrier subcontractor chose the optimum route to pick up deliveries from each supplier to deliver just in time. The trucks were controlled via satellite navigation (GPS). After delivery on site the trucks loaded sorted rest materials – and brought them to their respective return places [8].

Benchmarking has been introduced to construction during the 1990ies (UK). It means a systematic comparison between own and other's processes and products, leading to concrete following up measures. The concept was promoted by researchers and consultants, but has not been widespread. But it led to some groups of companies exchanging key performance indicators.

Business process reengineering – BPR - was another buzzword spreading to construction about 1995 – aiming at innovations more than incremental improvements. It gave opportunities to consultants but did not set roots in the first hand. It came up again within CIB around 2000 under the headline Business and Process Re-Engineering.

A method called SWOT – Strength, Weaknesses, Opportunities, Threats was launched for companies in the 1990ies. This was a process for developing strategies and business plans. It was hardly used in construction.

Concurrent engineering involves the parallel analysis of design and production methods. Design may be carried out simultaneously for several disciplines, resulting in system packages. The goal implies a better total result and shorter total time by starting production earlier. The concept was introduced in construction in the 1990ies.The ideas are continuously developed further in combination with new ICT means.

Lean construction is a still wider concept for improving productivity, including a number of rationalisation principles [9]. During the 1970-80ies some manufacturing and in particular automobile industries had achieved impressive improvements by combining a collection of philosophies. The ideas were adapted to construction in the 1990ies. The International Group of Lean Construction gathered researchers and industry for collective development. The main idea is to (1) make more efficient the conversion activities which add value to the product or information and (2) eliminate or improve reliability of the non-value-adding flows like inspection, waiting, moving. The movement might lead to a revitalization of the industrial scientific management from early 1900 as well as the adaptation to construction in the 1950ies.

Performance based building has since 1965 more or less continued to be a topic within CIB. A new Pro-Active Approach started 1998. About 20 working commissions are related to the topic. Financing is achieved from EU.

4 From focus on the building process to regulations and tick in a box

4.1 Quality in construction – a global revolution

The quality movement started up in manufacturing industries about 1950. Joseph Juran and Edwards Deming emphasised *constant improvement* in quality programs – connected with corporate overall planning. Juran established a worldwide consultancy. Deming introduced from 1950 the principles in Japan, establishing the *quality control circle* movement for workers, supervisors and specialists. His name is also connected to the use of cybernetics for systematic improvement, the *Deming cycle* as Plan-Do-Check-Act – PDCA. The *7 Quality Tools* were also well known from that period, like Fishbone and Pareto.

Armand Feigenbaum came up with the phrase *Total quality control* in the 1950s. Philip Crosby concentrated on *Zero defects*. Quality Awards were launched, first Malcolm Baldrige (US), then Deming (Japan) and EFQM (European) and national awards in most countries. A few large contractors won prices (US, Japan), but in total the appeal to construction was little [10].

Another approach to quality rose during the 1970ies. Manufacturing focused more systematically on customers' satisfaction. ISO issued the first quality assurance standards in the 9000 series in 1984. Before that some national standards existed. The introduction of Quality assurance, -control, -management, TQM and ISO standards in construction was a sort of revolutionary process. The major adaptations in construction were far from the industrial origins aiming at continuous improvement.

Companies could achieve certificates for accepted systems. Construction industry was led into this by massive information that the clients and market would require systems. As this sort of system and documentation of procedures was new for the construction sector it became a huge market for consultants and certification bodies [11, 12]. Year by year more ISO quality standards were presented or revised, altogether about 20. A first major revision was completed in 1994. In more than 10 years the ISO probably got its largest income from the sale of quality standards.

A minority was sceptic to the ways to formal documentation; Juran warned against ISO 9000 as well as the author of this paper [13]. A theoretical psychological analysis and practical study focused on the importance of a balance between the rational *structure* and the emotional or human *substance* [14]. Engineers and researchers in the area has mainly been concerned with the management tools – *the structure*. Too little effort might have been laid in the involvement of top managers as well as employees' participation in the process from beginning to end. Likewise the role of specialists (system, quality, safety etc.) might have been more substance oriented and working like coaches or change agents.

Enthusiasm and drivers might even appear from groups or clubs amongst companies. This was experienced 1985-95 by over 500 companies working in more than 50 groups. They followed a five-step club two years programme (Norway, Sweden, Finland, Iceland and The Netherlands). The implementation was not based on ISO but followed a model management system for construction. The structure was like a matrix: (1) Seven functions (later nine phases) in the building process and (2) Nine generic management aspects [15].

The quality standards were designed for manufacturing companies. Quality plan for construction projects was for years a much-discussed topic. The dissemination into construction seemed to include most of the world, partly with a time lag up to five years. And the regional cultures also affected greatly the sort of adapting. The more bureaucratic countries followed the ISO way. Construction industry in other countries was less affected.

A successful second major revision resulted in a new and radically improved concept in year 2000 [16]. The process focus fits construction rather good. But after 15-20 years of quality management in construction it seems to be less in focus. In most countries the quality consultancy and certification is no longer a profitable business, and the researchers have shifted topics. Lessons learned are about documentation of management of processes. Lessons forgotten are about continuous improvement. It is still strange to understand the power that really shaped this revolution in construction.

An important spin off is the authorities change of principles. In 1980ies started the incorporation of functional requirements in building regulations. In the late 1990ies another major change came about. Revisions of Plan and Building Act required that the actors in the building process should have a documented quality system (Norway 1997). Authorities inspectors should audit the systems instead of inspecting the work or site.

4.2 Safety and health in construction – from Unions to regulations

Like in manufacturing industries the construction trade unions have played a major role in improving the working conditions and the welfare of workers. The conditions have been negotiated with employers associations and specified in agreements. Authorities have issued regulations in various formats around health and safety precautions. Many countries have national recommended standards (UK-BS 8800 etc., US-OSHA). But an attempt around year 2000 to create an ISO standard failed. However, EU has its own directive, which has to be followed.

National and international organisations together with researchers studied risks and promoted precaution actions. ISSA has a section for the construction industry, and has actively arranged conferences. ILO has represented three partite viewpoints, and issued common frameworks. CIB members have worked on the topic within various commissions. Occupational health care service for contractors and construction workers were active in many countries in the 1970-80ies (Sweden, Bygghälsan). Their studies and research created detailed knowledge for precautions: Chemicals, noise, emissions, ergonomics, safety and psychosocial elements. Most of the problems were fully weaved into the design and production processes, and therefore more difficult to solve separately.

Around 1980 the stress due to shorter construction time was confirmed by research (Norway, Sweden). But it was a rather strong hypothesis that a professional process planning and control led to a smoother flow and less alterations, which were main causes to stress and accident risks. Another research project documented a positive effect of organised site meetings between workers from *all companies and professions* (Norway). This was a project application of some principles from industrial democracy, in particular important with many specialists working in parallel.

Seen over decades as well as globally the improvements have been significant. But the records are constantly bothering all parties. Strategies vary, and there is no common conclusion about the ways ahead. Precautions incorporated in design of buildings, in design of tools and machinery, in development of building products, in production methods, in protective means for production (guard rails etc) and for workers (helmet, clothes etc). Information, communication and control is another facet; education and learning, management, planning, records of injuries, involvement and representatives, specialists, focus actions, campaigns etc. Statistics, studies and risk analyses have been applied without significant documented long-term effects. One problem is that the direct and indirect costs or savings are little visible. They concern various “levels”, as individual, company, project, client or society. Some insurance systems help to show reality by premiums related to rate of injuries. A company may also choose to cover some costs of absenteeism after accidents, and thus have a motivation to reduce risks.

Safety representatives of workers and safety officers have since 1970-80ies been given duties in construction. The functioning can vary from a strong but quite separated specialist organisation to a coaching role for co-workers and for the production manager. The latter principle seems to be most in line with organisational psychology.

Authorities have played a major role in promoting safety. They had to face the change from main contractors with own workforce to the 1980ies or 1990ies with an increasingly number of specialist workers and small companies continuously entering and leaving the workplaces. The base for overall strategies and planning was diminishing. Therefore the authorities have shifted the responsibility for co-ordination of Occupational Safety and Health - OSH - over to clients or owners. Another major shift in the 1990ies was from site inspection over to require and to audit “internal systems” in companies and on sites for conformance to regulations. It resulted in a new consultancy wave for aid to documentation of procedures and forms for tick offs. Some shift to performance-based requirements seems also to be under way (UK, Australia and New Zealand).

The safety and health issue in construction is mainly seen as a separate matter in relation to the building process. Little focus has been on possible savings by incorporating safety in the process and focus on prevention in design of products and buildings [17]. The following hypotheses are only reflections of the author, and will surely stimulate to a debate. (1) Improvements in OSH are not looked at as value adding in relation to the end product – the building. (2) Neither is investing in OSH seen as a mean to reduce costs. (3) The main driving force to focus on OSH is conformance to regulations and contractual requirements from clients. (4) Ethics and human consideration is a bespoken concern as long as it does not decrease the profit. If the hypotheses have any reliability there is evidently challenges for the future. Some thoughts will be added in the last chapter.

4.3 Environment and sustainability – regulations and industry focus

Engagements concerning global sustainability got increasingly attention around 1990, with political agendas (Rio). Construction R&D was involved in the topic from mid 1990ies. National programmes were launched (Finland 1994, Sweden 1997 and Norway 1998).

Authorities introduced taxes for use of non-sustainable materials and differentiated fees for disposal of various sorts of rest products or waste materials. New regulations required environmental consequence analysis before building permit. Plans for amount and sort of waste and controlled transport to disposal should be accepted before construction or demolition work.

Construction industry took the lead in national programmes and set targets to avoid governmental goal setting. Improvement tasks were related to manufacturing of building products, design, site work and recycling of rest materials.

Challenges were both technical and managerial. Environmental properties of materials and products became crucial as well as the designed buildings. Composite products and prefabrications had to be redesigned for easy disintegration and recycling. Manufacturing had to adjust production methods to reuse rest materials. New business opportunities were created for transforming rest products into marketable stuff.

The managerial challenges were much about flow and conversion of materials. The similarity with logistics is evident. A first principle is to plan production in detail aiming at getting exact amount of materials at right time and place, avoiding cutting and left over. Second principle is to organise sorting and gathering of any rest and waste for maximum reuse or recycling. This concept includes close communication with designers (standard formats or manufacturing to order), factories, wholesalers, delivery transport, site transport, workers and left over handling. The potential of economical savings is great concerning cost of material, the entire handling and putting in place. Even a tidier workplace increases the productivity as well as reduces risks for injuries. The means could be based on paper and pencil, although data systems including Internet give fast and simple opportunities. A general impression from practice is too less focusing on logistics and a large remaining potential for cost reductions.

Another managerial approach is the establishment of an Environmental Management System – EMS – according to ISO 14000-serie of standards. The concept is much like the ISO 9000-serie for quality. ISO 14001 implies measurement of own environmental performance and continuous improvement. Again the concept is about companies and not easy to adapt to building projects. Certification is most widespread amongst building product factories. In some countries even larger contractors have established systems and got their certificate, while in other countries there is very little interest.

Construction businesses have since 1985 more or less experienced the development of management systems for quality, safety and health and finally environment. Each of the aspects has had their separate targets and driving forces. Each of the aspects involved experts in the development. The companies' processes for development and implementation varied largely, from external expert documentation to managers and employees full involvement. Each of the aspects led to separate documented systems. Each of the aspects led to a new internal expert function. None or few of the companies aimed at integration with their corporate management systems. At the end of the 1990ies almost all those companies that have been through the three phases are aiming for total system integration. The use of ITC may vary from simple to sophisticated. A combination of the three specialist functions is also under way. A main concern should be how the documented systems could be incorporated in the organisation to increase the practical use.

A Finnish construction company (Skanska Oy, 5000 employees) has in the period 1998-2001 implemented an integrated system for environment (certified according to ISO 14001) and occupational health and safety (certified according to BS 8800). The system is built into the existing quality system [18]. Measurements and indicators are through of a *balanced scorecard* system linked to the overall objectives and targets during a process involving people.

5 The future evolution of management systems in construction

5.1 Structural changes in construction influencing the evolution of management

This appraisal does not discuss any dramatic changes in world economy etc. Neither is it taken into account any great changes in needs of the market or users. Even the source of human resources is taken for stabile.

As a background before discussing the driving forces it might be relevant to recall some bad reputation connected with the building and construction sector. Improving the standing should be seen as a challenge:

- Quality failures
- HES – highest rate of fatalities, injuries and bad working conditions
- Environment – the worst industrial sector
- Overrun budgets and late deliveries
- Decreasing productivity
- Secret agreements, trust, black and grey economy

The following is a scenario based on changes towards businesses offering more total services. This has already been a vague trend during the 1990ies.

The market for the construction industry is possibly altering further from ordinary clients and owners for own use to developers and to property investors delivering *a total facility service*.

The structure of the construction industry will continue to change to serve the new trends of market. Most likely more companies will integrate in-house or provide both design and production – *a total construction contractor*. Likewise there may be further integrations between trade professions, like installation of El, HVAC and sanitary – *a total installation contractor*.

The supply market or wholesalers may also change structure to larger groups offering a wider range of products – *a total supplier*.

Transport contractors will widen their services to comprise delivery of a wider spectre of goods – *a total distributor*. A possible integration is also with the gathering of all sorts of rest materials and waste for transport to respective receiver for each sort – *a total collector*.

Investment entities may continue to take over business units and facilities as well as selling again, and influence the development – *a professional total investor*. Contractors may increase control over a greater part of the value chain as vertical integration via ownership or consortiums. Even illegal monopolizing via trusts may effect construction.

Authorities' regulations may strengthen requirements as to Plan and Building Acts and Environment to assure a built environment according to national and global goals. The issue may be raised of better integration between the various authorities regarding requirements to construction, as PBA, E and OSH. But it is not realistic to believe in any *total integrated requirements.*

The nature of regulations will increasingly be function or performance based. The already experienced change to authorities demand for "systems" in companies and audit of systems may slightly reverse to some sort of direct inspections.

International standardisation will continue a sort of integration between quality and environment – and probably also take up again the health and safety aspect – leading against *a total management standard.* Construction industry will establish a framework for *construction project management* (ISA TC 59 Building Construction, SC3, WG13 Management of construction and facilities).

R&D on managerial topics in general will continue to focus on companies in various contexts, manufacturing and other businesses. New industrial topics may be trendy without solving problems of construction. Investment in R&D for construction management may not increase. International funding may be explored more by construction. Topics will continue to be treated within industrial focused programmes and limited R&D teams. R&D on technical management aspects will most probably continue to dominate over human and social elements.

The technical development of construction will to some extent focus on adaptation to sustainable environment. It may be relatively less focus on safety and health.

5.2 Development of ICT as a driver for evolution of management systems

R&D on ICT will continue and result in increasingly new opportunities for application in management of construction. The developments the last decades are accelerating. The following listing show some important changes more or less in use or ready for use:

- From telephone net to wireless mobiles, evolution from conversation to sending, receiving and storing of text, data, pictures. Connection with other phones, computers, radio/TV, Internet including trading, sensors (start/stop heaters). Time registration.
- From network to wireless computers, portable, palm (converging with wireless mobiles).
- Increased transmission capacity, wireless broadband.
- Computer programmes solving increasingly complex tasks. CAD/CAM, 3D and 4D (production time and place). Timesharing in real time. Databases. Project management, scheduling and control.
- Internet services, improved information storing and retrieval, improved communication (databases, trading, project sites).
- Internet paid locations for efficient communication and filters to avoid information overflow and cumbersome disturbing advertisements.
- Digital cameras, monitors and videos for record and wireless transmission of pictures/movements, with sensors or programmes for start/stop, analyses of similarities (persons) etc. Scanners to convert from analogue to digital pictures.
- Sensors for programmed (wireless) actions or registrations upon various sort of impulses (movements, opening, locking, light, sound, words from speaking etc.).
- Magnetic coding for admittance (bank card, door opener), or may be by fingerprint.
- Various registration or recording devices (meteorology, speed, work order, optical readers of barcodes).
- GPS - satellite for location and navigation.
- Electronic labels (identity tag) as a next generation of barcodes, including identification data and other feasible information (receiver, place, time etc.)

Combinations of the newest ICT should have the potential of a leap in practical use also in construction industry. Both directly and indirectly this development would greatly affect the management systems for companies and projects.

5.3 Evolution of management systems related to the building process

Evolution of management systems has a bearing on structural changes in the industry. The further discussion is based on the previous scenario of movements towards more total service businesses.

The much bespoken integration of various aspects to management in construction is a remaining challenge. Some companies claim that they have developed integrated solutions. The first generations are mainly system databases where you can search for various aspects. What remains is a real activity process planning system where requirements of all aspects can be linked to each activity. The new open library systems should allow for this. Such a planning system should in the same time include advices according to basic planning principles. The lean construction recommendations could be a good concept. But anyhow, it is difficult to consider multiple management targets simultaneously.

Basically the knowledge of management is aggregated in companies even if it mostly is experiences from projects. Management systems in construction are above all related to projects and the building process. The following examples on possible evolution are sorted after the main phases of the building process: overall, design, production and operation. It is important at the same time to have in mind the dependence on the sort of organisation of the process and the kind of actors or companies being involved.

Overall:

- Project overall management systems will extend both in sort of content and by integrated use of ICT. Example with reference to Singapore: Construction and Real Estate NETwork – CORENET, electronic data superhighways, procurement and tender administration, concurrent design with real time sharing, quantities take off, inspection of critical areas.
- Electronic communication with authorities all through the building process, regarding building regulations, environment, safety and health.
- Contracting/procurement methods allowing for corresponding design and production, with proper distribution of liabilities. The goal is to create an environment for mutual cooperation within projects with several partners.
- Framework for object-oriented information exchange – for construction works (ISO committee). A reference library that will allow for structuring information only once. Thereafter it can be used in all connections and replaces all classification tables.

Conceptualisation and design:

- Functional or performance requirements regarding users needs, environment (life cycle) and safety and health, electronically linked together and with relevant regulations.
- Design process based on functional or performance requirements and with electronic communication between designers and contractors from all trades or crafts. Possibly link between building and construction elements and requirements database. Development of a new computerised version of Quality Function Deployment (QFD) over to All Functions (Requirements) Deployment. Timesharing, real time.
- Design process based on use of CAD 3D with integrated drawings and additional features for 4D (production model time/space planning). Direct communication between designer, engineer and contractors comprising all work from clearing, foundation, structures, installations, finishing and accomplishment.

- Design process based on electronic communication with building products database (search according to requirements, compare performance, choose).

Production:

- Production planning process linked electronically with CAD 3D/CAM 4D drawings, bill of quantities, requirements and with database for selection and order of material, to ensure conformance with design and authorities requirements.
- Co-ordinated planning between the contractors and suppliers, process charts and schedule linked electronically to the specifications and deliveries. Optimising the efficiency (value) of task performances and minimising the non-value adding flows.
- Scheduling programmes with links to functional requirements as well as details for production, time, place, resources, and requirements regarding the standard (quality), safety, environment, cost (amount of resources) etc. The new data library thinking may give impulses and new possibilities.
- Communicate plans with and to the operators (workers) to assure common understanding and conformance.
- Monitor processes for data retrieval and adjustments of plans. Collect site data with proper use of means, as palm and digital camera. Transfer information (wireless) to project computer and present results on common project website.
- Implement electronic cost control system linked to CAD, resources' unit prices, consumption and payment.

Operation and termination:

- Transfer of design information into formats suitable for facilities management etc. (This phase is not explored in the paper, but it has obviously great improvement potentials. One example is feedback of information to design).

Due to the nature of preview, the examples above are mostly indications and not precise specifications. But they are mainly close to realities that could be achieved within a decade or so.

It might also be of interest to look further into the future as visions or science fiction. The following examples are based on continuing development of ICT and by more innovative use of known or close to ready technologies:

- Totally object-oriented electronic databanks or libraries. This simplifies information storage and retrieval, and opens for further integration of various aspects during planning and scheduling.
- Logistics, integrated management systems, just in time/supply chain, lean production, manpower flow, planning system including activities, needed resources, where, when, work orders, transport devices onsite delivering right in place, budget and cost control integrated with orders and invoices, OSH and Environment control included.
- Electronic labels replacing traditional barcodes, thus giving the opportunity to rather sophisticated logistics. Each product (even individual parts) from factory or wholesaler can be labelled electronically via a computer. The label contains precise references, like 3D/4D code for what and where to be installed, time for delivery/use and who is installing. A next generation of local GPS may even locate the product during its transport and installation. And to continue the vision; the label can be used in management of maintenance as well as during a final destruction and the way to recycling.

- Application on building sites of the next generation of sensors and camera or video monitors to improve logistics and the flow of work in combination with electronic labels.
- Electronically observing and tracking of production methods, performance, automatically experience data bank and proposals for improvements.
- Finally to mention a vague vision of a *cybernetic total management system* to cover the building process and linking together the actors (plan, do, check, act cycle). This will most probably “never” happen.

5.4 Evolution of the human substance in management systems

Before in this paper is referred to the importance of a balance between the rational *structure* and the emotional or human *substance* [14]. The examples on future evolution of management systems are all connected with the technical and rational structure. The IT development may too much be a magnet for technologists without knowledge or understanding of the human aspects. The human beings are not basically changing. ITC is changing managers, designers, engineers and workers working conditions. We need simple methods to follow, even though we may become accustomed to evolutionary use of new IT tools. Therefore more than ever we are dependent of using all our knowledge about how to involve people in a positive manner to adopt and implement new instruments. We have access to a vast knowledge about the principle from recent decades. This may be the most critical aspect in the next decade. And it seems still to be underestimated in all development, as well in the creation of new tools as in construction management research in general.

Improvement of workers health and safety conditions is not specifically focused in the foreseen prioritised developments of building process management. It might be seen as a challenge to change the regulatory driven evolution to an integrated part of the building process management. All possible means should be used to demonstrate ways to increase productivity, both directly and indirectly. It is necessary to convince the managers that they can win in improving the working conditions. A management positive feeling to working environment and safe production methods increases the working spirit, saves man-hours, and reduce costs due to injuries and absenteeism. This is not new, but it might be necessary to lay back the human empowerment and the formal representation of OHS as a specialist function. The other way around is increasing the involvement of people with the dual goal of productivity and OHS. This could also contribute to the human balance in management systems.

The never-ending story of evolution

Even though there have been significant improvements they come about as evolutions. The resources for improvement and R&D in construction are extremely fragmented and widespread with individual targets. The construction industry does not represent a common market with enough volume for ICT companies to tailor real innovative and efficient systems or tools to fit the building and construction process.

Management systems can alone never improve the records of bad reputation in a *revolutionary* manner. The only hope might be to combine with a real technical industrialisation in construction. The needed knowledge already exists. The vision of a future *revolution* could be our common message to broadcast globally for dissemination in strategies and goals for R&D.

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Integrated Management Systems in Construction (IMSinCONS)

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Abstract

The implementation of integrated management systems in construction, together with cost and time controls, is recognised as an effective tool to optimise the resources to implement and maintain environmental, quality and occupational safety and health systems. The objective is to promote the improvement of the quality of the constructed facility (a building, a bridge, a road), to reduce the environmental pollution and to reduce the occupational accidents and professional diseases. Societal demands (environment), client's demands (quality, including cost and time constraints) and workers' demands (occupational safety and health), as well as legislative requirements, are the primary forces leading the industry to a better quality of life for all parties. To achieve this objective on a construction project there is a need to act, beginning at the inception, design and planning phase of the project through its execution and utilisation/exploitation phases. Owners and company managers play a strong role in this objective. They should define the policy for each project, considering and prioritising the concerns not only of cost and time, as traditionally, but also taking into account the environmental, quality and occupational safety and health issues. They should also give the authority and power to those who are assigned by them (or acting on their behalf) the responsibility to implement and maintain their policy, and allocate the human and material resources that are needed to carry out the policy. The practical implementation of any policy is mainly a problem of organisation and responsibility - the two "columns" of any management system. In this paper, an approach to implementing an integrated management system based on ISO 9001:2000 is presented and discussed taking into account recent cases of relevant construction projects.

Keywords

IMSinCONS; ISO 9000; ISO 14000; ILO/OSH 2001; EU Directive 92/57/EEC.

1 Introduction

Construction Project Management (CPM) and Construction Management (CM) are two concepts very well known by all construction experts, but some times different meanings are used in some countries. The first (CPM) considers the management of the entire cycle of the development of a construction project, from inception, design and planning to project startup, sometimes, to the end of the "assurance period" (usually, 5 -10 years after the execution phase, largely depending on the country). The second (CM) typically includes the management effort during the execution phase, and sometimes it may include the contract award phase (it usually does not include the design phase). In the CPM format, the owner designates the so-called "Project Manager" and in the CM format the owner designates the so-called "Construction Manager". In both cases, this manager could be the owner’s in-house personnel if the owner has such capabilities, but often it is an external expert (single person or an organization, acting on behalf of the owner). In some cases (e.g. European Union Directive 92/57/EEC), these professionals are also called “Project Supervisors” being responsible for supervising the design and/or the execution of the project. When their responsibilities are restricted to the design phase, they are usually called “Project Supervisors for the design phase/stage” and when their responsibilities are restricted to the execution phase they are usually called “Project Supervisors for the execution (or construction) phase/stage”.

When a CM approach is considered, the construction manager, acting on behalf of the owner, has the primary duty of overseeing (and to assure the accomplishment of) the contracts established between the owner and the various contractors. In many cases, they do not participate in the formulation of these contracts and, additionally, they have no responsibility in the quality for the design documents. They supervise the construction of the project based on the owner’s requirements included in the contract with the contractors. If the requirements are not appropriate or the design documents are poor, the construction manager usually has a reduced responsibility for the quality of the final product. If this condition exists, it may be more difficult for the project execution to be successful and the objectives defined by the owner may also be more difficult to be achieved.

On the other hand, in a CPM approach the project manager will have the responsibility for the entire process, including design documents approval and the supervision of the contract documents with the contractors. The implementation of an integrated management system has, in this case, a greater probability of being successful depending on the commitment and the skilfulness of the project manager team, of the design team and of the contractor team (staff personnel, subcontractors, workers). In some cases, the CPM approach is also complemented with a CM team, acting under the responsibility of the project manager.

This paper is organised in three main sections. In the first, some requirements for implementing an integrated management system (IMS) in construction are presented. The following section refers to the identification of the main documents and the hierarchy of an IMS in construction. The next section refers to a proposed structure for the main documents identified in the previous section, which is based mainly on the ISO 9001:2000, taking into account the ISO 14001:1996, the guide ILO/OSH 2001 and the ISO 10006:1997. Finally, some conclusions and recommendations are provided, to assist in the generation of a discussion that is needed on these matters between all construction experts.

2 Requirements to implementing an IMS in a Construction Project

The successful implementation of an integrated management system for a construction project using the CPM approach, relies on the ability of the design team and of the construction team and must be planned at the very beginning of the contract award process. It is then essential to evaluate the team's ability to assure a high probability of success of the management system.

The parties to the construction process should be prepared and organised in two sections: (i) requirements for the implementation of the IMS to be considered in the contract award phase; and (ii) requirements to be considered during the design and execution phases.

The first "requirements" should be included in the "competition programme", which contains the rules for awarding the contract and they must be followed by all potential competitors. The second "requirements" should be included in the "specifications", which contain the rules during the design and execution phases of the construction project and they must be followed by the successful contractor.

2.1 Requirements to be considered in the contract award phase

During the contract award phase, the ability of the competitors should be evaluated prior to final selection. This can be done through the inclusion of the requirements needed for this evaluation. The competitors must demonstrate their ability to use the appropriate management techniques integrating the environment, the quality and the occupational safety and health issues, as well as cost and time controls. Within the guidelines of the compulsory legislation, the international standards ISO 9001:2000 (quality) and the ISO 14001:1996 (environment) may be considered, together with the guide ILO/OSH 2001 and, when applicable, also the European Union Directive 92/57/EEC.

This demonstration should be based on the integrated management system that the competitor proposes to implement for the construction project under consideration. For this purpose, a technical note with a brief description of the proposed system may be required considering the following: (i) a declaration of the formal management policy to be implemented in the construction project under consideration, which must include statements related to the environmental, quality and occupational safety and health issues, as well as cost and time; (ii) the need to show the accuracy of the system to assure a correct and adequate environmental performance, the quality of the services to render, and the occupational safety and health concerns, having in mind the design, the execution and the utilisation/exploitation phases; (iii) it should be based on the standards and guidelines referred to above, and also on the legislation applicable to the construction project under consideration; in the case of changes of any of these documents during the process of the construction project the system shall be updated as necessary; (iv) it should include a nominal organisational chart for the construction project under consideration, together with the curricula and the functions of all relevant personnel that have an influence on the management of the system; the expert that will assume the responsibility for the management of the integrated management system must also sign a declaration to act with dedication, assiduity and proficiency; (v) it should consider the different and specialised work to carry out the construction project under consideration; (vi) it should include the structure of the IMS and also the list and a brief description of the formal procedures to be developed for the project (applicable to quality, environment, safety and health); (vii) it should include the structure of specific plans needed, namely, monitoring, measuring, and controlling environmental, quality and safety and health issues.

2.2 Requirements to be considered during the design and execution phases

The potential competitors must adhere to the previous requirements on presenting their proposals to carry on the project.

The implementation of any management system involves resources and their related costs. This means that during the contract award phase, the specifications must define the requirements to develop the integrated management system.

The specifications must then state, for example, that the contractor has the obligation to establish, maintain and implement an IMS based on the technical information presented during the contract award phase and taking into account any comments made by the owner's staff. This system must be in conformance to all the applicable legislation related to the environment, quality, safety and health, and it must fulfil all the elements of ISO 9001 (quality), ISO 14001 (environment), ILO/OSH 2001 and, when applicable, the European Union Construction Sites Directive 92/57/EEC (safety and health). It can also be stated that the system must be based on the structure of ISO 9001 introducing the necessary adaptations to fulfil all the above mentioned elements.

The IMS should: (i) include an adequate plan to cover the three areas (environment, quality and safety and heath) and the associated procedures, and include the specific monitoring, measurement and prevention plans, work instructions, and audit program, taking into account the different work involved in the project; (ii) consider the creation of IMS working commission for each construction site and for the project as a whole (in this case representatives of the owner will be included); this commission is intended to follow up the implementation of the system; (iii) take into account and be compatible with the organisational structure of the owner.

The specifications must also include some statements to clarify the relationship between the owner (or owner's representative) and the contractor as, for example, the followings: (i) during a fixed period (e.g., two months) after the contract is signed, the contractor must present the IMS according to the above mentioned requirements, as well as an implementation plan, allowing the owner sufficient time (e.g., one or two months) to introduce changes to the proposed system ; (ii) without prejudice of the above mentioned periods, no relevant activity related to the design or to the execution phase can start before the contractor presents the plan for assuring the accuracy of that activity, concerning the environment, quality and safety and health; (iii) the owner has the power to audit the IMS in any time beginning three months after the contract is signed and the contractor has the obligation to implement the changes needed as a result of any recorded non conformity; the owner may also participate in the audits carried out by the contractor with any subcontractors; (iv) the owner may order the creation of new records or redefine the scope and extent of the traceability, and the contractor must reformulate the system within one month or within an agreed period depending on the extent of the changes to be introduced; (v) the owner is entitled to access to all documentation and records of the IMS (including that of the contractor and the subcontractors), including internal audit reports and the owner may also ask for hard copies of this documentation; (vi) the contractor must propose the assignment of a responsible (manager) for the IMS, who is subject to approval by the owner; this manager is responsible for the implementation, maintenance and the continual improvement of the system; this individual's qualifications must be specified for each project (e.g. requirement to be a civil engineer, possess at least 10 years of documented experience, etc.); in the case of very important projects, it can also be required that this manager be assisted by an expert for each of the areas (environment, quality and safety and health); these assistant managers must also be qualified in the respective area of expertise; (vii) the contractor must bear the costs of assigning all the resources needed to implement an effective IMS; the owner may also require, at the expenses of the contractor, the installation or use of any collective or personnel equipment recognised to be essential for the improvement of the system; (viii) at the end of the project, the contractor must provide all the relevant IMS documentation, including, the records generated, the tracking documents, safety and health plans, safety and health files, maintenance plans, etc.; (ix) the contractor must conduct a survey of all situations related with work that can affect third parties, namely, of the existing buildings and other installations in the area of influence of the project; this survey must include inspections of buildings or installations, the use of documentary reports of the initial situation and the follow up; (x) the contractor must present a monthly report summarising the situation on the implementation of the IMS during the project (design and execution phases); this report must be organised for each construction site and for the project as a whole; it is intended to evaluate the performance and progress of the IMS during the period of the contract; the model of this report must be proposed by the contractor within 2 months after the contract is signed; the owner may order the introduction of changes, namely, other relevant information needed for this evaluation.

3 Documentation in an IMS in construction and its hierarchy

An integrated management system may be organised and structured in different ways. It is the author's belief that a system involving the areas of quality (including cost and time controls), environment, and safety and health, must include the elements of the international standards ISO 9001 and ISO 14001, and also the elements of the ILO/OSH 2001 on safety and health and, when applicable, they should also meet the requirements of the European Union Directive 92/57/EEC. It may also consider the ISO 10006:1997 on quality to project management.

Of the mentioned areas, the implementation of quality systems is the most widely known and the most widely used in the construction industry, where considerable experience has already identified many of the strong and weak points. Therefore, the author believes that in the construction industry an integrated management system should be based and aligned the ISO 9001, which must be adapted to accommodate the elements for the other areas that are not included or related to any element of this standard.

The documentation of an integrated management system in construction and its hierarchy could be similar to the one shown in Figure 1, which is briefly described below.

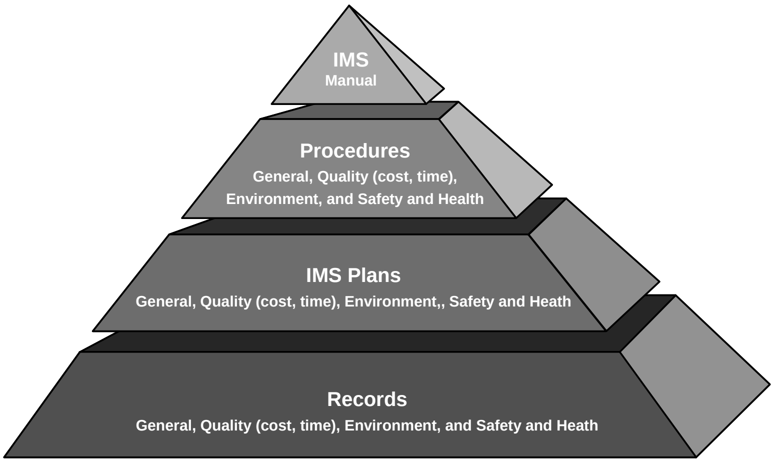

Figure 1 – Documentation of an IMS in construction and its hierarchy

According to this figure, the IMS includes the following main documents:

- IMS Manual (for the whole organization);
- IMS Procedures (those that are common or general to the three areas, those related specifically to quality including cost and time, those related specifically to the environment, and those related specifically to safety and health);
- IMS Plans (for each construction project, which may include and/or be related to specific plans on quality, environment, and safety and health);
- IMS Records (documentation of the implementation of the system).

The IMS Manual is the main document of the integrated system and should be prepared when the system is to be implemented by a construction company, i.e. for the whole organization. It defines the general rules for the entire organization and it contains the management policy, the structure of the organization and the responsibilities of all personnel of the organization that influence the management of the organization. This manual can be developed to meet the elements presented in section 4, i.e., it may be organized by following the elements considered in the proposed structure.

The IMS Procedures must complement the information of the manual. They must be detailed with the necessary information needed for the most relevant elements of the manual, including the procedures mentioned in the ISO 9001 and ISO 14001 standards. For example, the “control of a nonconforming product” requirement may refer to a written procedure describing the operational process for this control. It is recommended that all procedures be grouped in one single dossier, usually called the “Procedures Manual”.

The IMS Plans are documents with particular information concerning each construction project of the organization. They must conform to the IMS manual and to the applicable laws and regulations, in particular in the areas of environment and safety and health. They must set up the specific preventive measures to be implemented for a particular construction site, taking into account the construction processes and the working methods that will be used. There will be as many plans in an organization as there are construction projects undertaken by the organization.

The IMS system will also include the work instructions, documents describing the work process concerning each construction operation. These working instructions are the basis to identify and assess the monitoring, measurement and hazards involved in the execution of any construction operation and to define the appropriate corrective and/or preventive measures that must be implemented to avoid or reduce the risk of poor quality work and the occurrence of injuries/diseases. They are essential documents for the definition of the monitoring, measurement and hazard prevention plans.

For the implementation of the IMS in the construction industry, there are two situations to be considered: (i) the system is to be implemented in an organisation (a construction related company) or; (ii) the system is to be implemented on a specific construction project. In the first case, the organisation should consider developing all the above mentioned documents. In the second case, it should consider developing just the relevant plans (and their related documents, e.g. procedures, monitoring, measurement and hazard prevention plans, etc.). In some cases the organisation and the construction project may be the same entity (as is the case when a group of companies join to perform a specific project, e.g. consortiums, joint-ventures, groups of economic interests). In these cases, the organisation should decide on developing either an IMS Manual or an IMS Plan for that specific construction project, but not both.

Once the documentation and its hierarchy are identified, the next step is to establish the contents of the IMS manual and/or plan, as described further in the next section.

4 Proposed structure of the main documents in an IMS in construction

On the practical level, the IMS Manual (for an organisation) and/or the IMS Plan (for a specific construction project) should consider all the applicable elements of the standards and/or guidelines related to the three areas as mentioned above: ISO 9001:2000 for quality, ISO 14001:1996 for environment and ILO/OSH 2001 for occupational safety and health. As the issue is construction, the ISO 10006:1997 (Guidelines to quality in project management) should also be considered. Moreover and related to safety and health, the UK specification OHSAS 18001:1999 is also to be considered in this analysis.

Of the above-noted standards or guidelines, ISO 9001:2000 is the broadest, i.e. it includes the most detailed list of elements related to management. So, this standard (Figure 2) will be taken as a basis for the comparison to the others in view of identifying and analyzing their relationships.

Elements of the ISO 9001:2000	
1 Scope	**7 Product realization**
1.1 General	7.1 Planning of product realization
1.2 Application	7.2 Customer-related processes
2 Normative reference	7.2.1 Determination of requirements related to the product
3 Terms and definitions	7.2.2 Review of requirements related to the product
4 Quality management system	7.2.3 Customer communication
4.1 General requirements	7.3 Design and development
4.2 Documentation requirements	7.3.1 Design and development planning
4.2.1 General	7.3.2 Design and development inputs
4.2.2 Quality manual	7.3.3 Design and development outputs
4.2.3 Control of documents	7.3.4 Design and development review
4.2.4 Control of records	7.3.5 Design and development verification
5 Management responsibility	7.3.6 Design and development validation
5.1 Management commitment	7.3.7 Control of design and development changes
5.2 Customer focus	7.4 Purchasing
5.3 Quality policy	7.4.1 Purchasing process
5.4 Planning	7.4.2 Purchasing information
5.4.1 Quality objectives	7.4.3 Verification of purchased product
5.4.2 Quality management system planning	7.5 Production and service provision
5.5 Responsibility, authority and communication	7.5.1 Control of production and service provision
5.5.1 Responsibility and authority	7.5.2 Validation of processes for production and service provision
5.5.2 Management representative	7.5.3 Identification and traceability
5.5.3 Internal communication	7.5.4 Customer property
5.6 Management review	7.5.5 Preservation of product
5.6.1 General	7.6 Control of monitoring and measuring devices
5.6.2 Review input	**8 Measurement, analysis and improvement**
5.6.3 Review output	8.1 General
6 Resource management	8.2 Monitoring and measurement
6.1 Provision of resources	8.2.1 Customer satisfaction
6.2 Human resources	8.2.2 Internal audit
6.2.1 General	8.2.3 Monitoring and measurement of processes
6.2.2 Competence, awareness and training	8.2.4 Monitoring and measurement of product
6.3 Infrastructure	8.3 Control of nonconforming product
6.4 Work environment	8.4 Analysis of data
	8.5 Improvement
	8.5.1 Continual improvement
	8.5.2 Corrective action
	8.5.3 Preventive action

Figure 2 – Elements of ISO 9001:2000

ISO 9001:2000 versus ISO 14001:1996

In figure 3 the main elements of ISO 9001 are compared with those of ISO 14001, especially those elements that facilitate the analysis. From this figure, it is possible to identify some of the elements of ISO 14001:1996 that have a clear similarity to one or more of the elements of ISO 9001:2000, while others have some similarity. Where the contents and focus are different, some adaptations need to be considered and introduced. This is the case, for example, of the Policy which is focused on quality in ISO 9001 and on environmental issues in ISO 14001. The integration of these two issues in the same policy does not offer any difficulty and even sounds appropriate. The same approach should be followed concerning the objectives and targets which are different for quality and for environment.

On the other hand, some elements of the ISO 14001 do not appear to be related, i.e. they have no explicit reference counterpart although they could be considered in one or more elements of the ISO 9001. This is the case, for instance, of the legal and other requirements (ISO 14001 - 4.3.2), which could be included in the “customer-related processes” (ISO 9001 – 7.2). Another case is the topic of “emergency preparedness and response” (ISO 14001 - 4.4.7), which could be considered for example in “control of non conforming product” (ISO 9001 – 8.3).

Main elements of ISO 9001:2000	Elements of ISO 14001:1996																	
	4.1	4.2	4.3.1	4.3.2	4.3.3	4.3.4	4.4.1	4.4.2	4.4.3	4.4.4	4.4.5	4.4.6	4.4.7	4.5.1	4.5.2	4.5.3	4.5.4	4.6
4 Quality management system																		
4.1 General requirements	X																	
4.2 Documentation requirements										P						P		
5 Management responsibility																		
5.1 Management commitment							X											
5.2 Customer focus																		
5.3 Quality policy		X																
5.4 Planning					P	P												
5.5 Responsibility, authority and communication							P		P									
5.6 Management review																		X
6 Resource management																		
6.1 Provision of resources							X											
6.2 Human resources							X	P										
6.3 Infrastructure							X											
6.4 Work environment							X											
7 Product realization																		
7.1 Planning of product realization												X						
7.2 Customer-related processes			P	P					P			P						
7.3 Design and development											P	X						
7.4 Purchasing												X						
7.5 Production and service provision												X						
7.6 Control of monitoring and measuring devices														X				
8 Measurement, analysis and improvement																		
8.1 General														X				
8.2 Monitoring and measurement														X			P	
8.3 Control of nonconforming product													X		X			
8.4 Analysis of data														X				
8.5 Improvement							P								P			

X Identified relation (explicit reference) P Partial relation (non explicit reference although may be implicit)

Elements of ISO 14001:1996	
4.1 General requirements	4.4.4 Environmental management system documentation
4.2 Environmental policy	4.4.5. Document control
4.3 Planning	4.4.6 Operational control
4.3.1. Environmental aspects	4.4.7 Emergency preparedness and response
4.3.2. Legal and other requirements	4.5 Checking and corrective action
4.3.3. Objectives and targets	4.5.1 Monitoring and measurement
4.3.4. Environmental management programme	4.5.2 Noncorformance and corrective and preventive action
4.4 Implementation and operation	4.5.3 Records
4.4.1 Structure and responsibility	4.5.4 Environmental management system audit
4.4.2 Training, awareness and competence	4.6 Management review
4.4.3 Communication	

Figure 3 - Relation between ISO 9001:2000 and ISO 14001:1996 elements

The elements of ISO 14001 that ISO 9001 should accommodate in an explicit way (whether considered in one or more elements of this standard) are: legal and other requirements (3.2); communication between management and the population (4.4.3); and emergency preparedness and response (4.4.7).

ISO 9001:2000 versus ILO/OSH 2001

A second step is to compare the elements of ISO 9001 with those of ILO/OSH 2001 and analyse their relationship with a focus on identifying duplications between them (Figure 4). The elements of this guide are also presented to facilitate the analysis.

This figure shows that most elements of ILO/OSH 2001 could be covered by one or more elements of ISO 9001, although some unclear relationships can be identified in some elements, i.e., there is no obvious counterpart of some elements. This is the case of the "worker participation" (element 3.2), which is a very important element of ILO/OSH 2001. The "emergency prevention, preparedness and response" (element 3.10.3) and the "investigation of work-related injuries, ill health, diseases and incidents and their impact on safety and health performance" (element 3.12), are elements that have no obvious counterpart in ISO 9001, but they could be considered as one or more elements of ISO 9001 extending the concept to accommodate theses issues.

The elements of ILO/OSH 2001 that ISO 9001 should accommodate in an explicit way (whether in one or more elements of the standard) are: worker participation (3.2) through at least the recognition by management of the workers' representatives and the promotion of the safety and health committees; communication (3.6) between management and the workers and their representatives; prevention and control measures (3.10.1) at the level of the management responsibility and at the level of product realization; management of change (3.10.2); emergency prevention, preparedness and response (3.10.3); procurement and contracting (3.10.4 and 3.10.5); investigation of work-related injuries, ill health, diseases and incidents, and their impact on safety and health performance (3.12).

Main elements of ISO 9001:2000	Elements of ILO/OSH 2001 GUIDELINES															
	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	3.11	3.12	3.13	3.14	3.15	3.16
4 Quality management system																
4.1 General requirements																
4.2 Documentation requirements					X					P						
5 Management responsibility																
5.1 Management commitment																
5.2 Customer focus																
5.3 Quality policy	P															
5.4 Planning								P	P							
5.5 Responsibility, authority and communication		P	P			P										
5.6 Management review							X							X		
6 Resource management																
6.1 Provision of resources																
6.2 Human resources				P												
6.3 Infrastructure																
6.4 Work environment																
7 Product realization																
7.1 Planning of product realization								P								
7.2 Customer-related processes										P						
7.3 Design and development								P								
7.4 Purchasing										P						
7.5 Production and service provision																
7.6 Control of monitoring and measuring devices																
8 Measurement, analysis and improvement																
8.1 General																
8.2 Monitoring and measurement											P	P	P			
8.3 Control of nonconforming product										P			P			
8.4 Analysis of data														X		
8.5 Improvement															P	P

X Identified relation (explicit reference) P Partial relation (non explicit reference although may be implicit)

Elements of theILO/OSH 2001 Guidelines	
Policy	3.10.2 Management of change
3.1 Occupational safety and health policy	3.10.3 Emergency prevention, preparedness and response
3.2 Worker Participation	3.10.4 Procurement
Organizing	3.10.5 Contracting
3.3 Responsibility and accountability	Evaluation
3.4 Competence and training	3.11 Performance monitoring and measure
3.5 OSHMS documentation	3.12 Investigation of work-related injuries, ill health, diseases and incidents, and their impact on safety and health performance
3.6 Communication	3.13 Audit
Planning and Implementation	3.14 Management review
3.7 Initial review	Action for improvement
3.8 System planning, development and implementation	3.15 Preventive and corrective action
3.9 OSH objectives	3.16 Continual improvement
3.10 Hazard prevention	
3.10.1 Prevention and control measures	

Figure 4 - Relation between ISO 9001:2000 and ILO/OSH 2001

ILO/OSH 2001 versus OHSAS 18001:1999

Related to occupational safety and health, the specification OHSAS 18001:1999 issued by BSI (British Standards Institution) in 1999, before the publication of the internationally recognised guide from ILO, should also be compared with the ILO/OSH 2001 (Figure 5).

This figure shows that most elements of the specification OHSAS 18001:1999 are covered by the ILO/OSH 2001 guide. The main aspects in this guide not explicitly addressed by OHSAS 18001 include: (i) training should be at no cost and during the working hours (3.4.4); (ii) employer should establish a safety and health committee and he should recognise the worker’s representatives (3.2); (iii) OSH requirements should be incorporated into the purchasing specifications (3.10.4) and in contracting (3.10.5); (iv) management of change (3.10.2).

Some of these issues may be considered implicit in OHSAS 18001 or be considered as facultative, leaving to management the decision for their consideration, i.e. this specification does not exclude the possibility.

ILO/OSH 2001GUIDELINES	Elements of the Specification OHSAS 18001:1999																	
	4.1	4.2	4.3.1	4.3.2	4.3.3	4.3.4	4.4.1	4.4.2	4.4.3	4.4.4	4.4.5	4.4.6	4.4.7	4.5.1	4.5.2	4.5.3	4.5.4	4.6
3. The occupational safety and health management system in the organisation	X																	
Policy																		
3.1 Occupational safety and health policy		X																
3.2 Worker Participation								P	P									
Organizing																		
3.3 Responsibility and accountability							X											
3.4 Competence and training								X										
3.5 OSHMS documentation				X						X	X					X		
3.6 Communication									X									
Planning and Implementation																		
3.7 Initial review			P	P														
3.8 System planning, development and implementation			X		P	X	P											
3.9 OSH objectives					X													
3.10 Hazard prevention			X															
3.10.1 Prevention and control measures			X	P								X						
3.10.2 Management of change			P									P						
3.10.3 Emergency prevention, preparedness and response													X					
3.10.4 Procurement												X						
3.10.5 Contracting			P									X						
Evaluation																		
3.11 Performance monitoring and measure														X				
3.12 Investigation of work-related injuries, ill health, diseases and incidents, and their impact on safety and health performance															X			
3.13 Audit																	X	
3.14 Management review																		X
Action for improvement																		
3.15 Preventive and corrective action															X			
3.16 Continual improvement					P													

X Identified relation (explicit reference)   P Partial relation (non explicit reference although may be implicit)

Elements of OHSAS 18001:1999	
4 OH&S management system elements	4.4.3 Consultation and communication
4.1 General requirements	4.4.4 Documentation
4.2 OH&S Policy	4.4.5 Document and data control
4.3 Planning	4.4.6 Operational control
4.3.1 Planning for hazard identification, risk assessment and risk control	4.4.7 Emergency preparedness and response
4.3.2 Legal and other requirements	**4.5 Checking and corrective action**
4.3.3 Objectives	4.5.1 Performance measurement and monitoring
4.3.4 OH&S management programme	4.5.2 Accidents, incidents, non-conformance and corrective & preventive action
4.4 Implementation and operation	4.5.3 Records and records management
4.4.1 Structure and responsibility	4.5.4 Audit
4.4.2 Training, awareness and competence	**4.6 Management review**

Figure 5 - Relation between ILO/OSH 2001 and OHSAS 18001:1999

ISO 14001:1996 versus ILO/OSH 2001

It should be noted that ISO 14001 and ILO/OSH 2001 are similar on the core issues as both are hazard prevention oriented, although in many cases these hazards are different. For example, the element 4.3.1 of ISO 14001 is referred to as "environmental aspects" ("an element of an organisation's activities, products or services, which can interact with the environment") which is related to environmental hazard identification (e.g. noise emission may cause an "environmental impact", such as noise disturbance). In ILO/OSH 2001 the element 3.10.1 (prevention and control measures) includes safety and heath hazards identification as a basis for the definition of prevention and control measures. It can be said that both ISO 14001 and ILO/OSH 2001 have the same concerns, although with different contents and objectives.

It should also be noted that on construction sites, it is not easy to distinguish an environmental hazard from a safety and health hazard in many situations. For example, noise emissions or dust on a construction site are hazards that should be evaluated, eliminated or reduced to address the safety and health of the construction workers, but this effort will also provide an environment improvement as it relates to the population.

ISO 9001:2000 versus ISO 10006:1997

Another important standard that should be considered in this analysis is ISO 10006:1997 (Guidelines to quality in project management), which is related specifically to the construction sector, although the author does not know any construction project where it has been implemented in a practical manner. In figure 6 the main elements of this standard, which are also presented to facilitate the analysis, are compared with those of ISO 9001.

Main elements of ISO 9001:2000	ISO 10006:1997 - Guidelines to quality in project management															
	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10	5.11	6
4 Quality Management system																
4.1 General requirements					X											
4.2 Documentation requirements	X	X	X	X												
5 Management responsibility																
5.1 Management commitment						X										
5.2 Customer focus						X										
5.3 Quality policy																
5.4 Planning		X					X									
5.5 Responsibility, authority and communication						X										
5.6 Management review		X				X										
6 Resource management																
6.1 Provision of resources											X	X				
6.2 Human resources											X	X				
6.3 Infrastructure																
6.4 Work environment						X										
7 Product realization																
7.1 Planning of product realization							X	X	X							
7.2 Customer-related processes													P			
7.3 Design and development								X								
7.4 Purchasing						X		X							X	
7.5 Production and service provisition								P								
7.6 Control of monitoring and measuring devices																
8 Measurement, analysis and improvement																
8.1 General																
8.2 Monitoring and measurement																
8.3 Control of nonconforming product																
8.4 Analysis of data																
8.5 Improvement						P										X

X Identified relation (explicit reference) P Partial relation (non explicit reference although may be implicit) Non identified relation

Elements of ISO 10006:1997 - Guidelines to quality in project management	
4 Project characteristics	5.6 Cost-related processes
4.1 General	5.6.1 Cost estimation
4.2 Project management	5.6.2 Budgeting
4.3 Organization	5.6.3 Cost control
4.4 Project phases and project processes	5.7 Resource-related processes
5 Quality in project management processes	5.7.1 Resource planning
5.1 General	5.7.2 Resource control
5.2 Strategic process	5.8 Personnel-related processes
5.2.1 Satisfaction of the customer's and other stakeholders' stated and implied needs is paramount	5.8.1 Definition of project organizational structure
5.2.2 A project is carried out as a set of planned and interdependent processes	5.8.2 Staff allocation
5.2.3 Focus on quality of both processes and products is necessary to meet the project objectives	5.8.3 Team development
5.2.4 Management is responsible for creating an environment for quality	5.9 Communication-related processes
5.2.5 Management is responsible for continual improvement	5.9.1 Communication planning
5.3 Interdependency management processes	5.9.2 Information management
5.3.1 Project initiation and project plan development	5.9.3 Communication control
5.3.2 Interaction management	5.10 Risk-related processes
5.3.3 Change management	5.10.1 Risk identification
5.3.4 Closure	5.10.2 Risk assessment
5.4 Scope-related processes	5.10.3 Risk response development
5.4.1 Concept development	5.10.4 Risk control
5.4.2 Scope development and control	5.11 Purchasing-related processes
5.4.3 Activity definition	5.11.1 Purchasing planning and control
5.4.4 Activity control	5.11.2 Documentation of requirements
5.5 Time-related processes	5.11.3 Evaluation of subcontractors
5.5.1 Activity dependency planning	5.11.4 Subcontracting
5.5.2 Estimation of duration	5.11.5 Contract control
5.5.3 Schedule development	6 Learning from the project
5.5.4 Schedule control	

Figure 6 - Relation between ISO 9001:2000 and ISO 10006:1997

This figure shows that most elements of ISO 10006 could be covered by one or more elements of ISO 9001, although at least two of them were more difficult to identify as having a clear counterpart, namely elements 5.6 – Cost-related processes and 5.10 – Risk-related processes. These elements together with others (such as 5.5 - Time-related processes and 5.11.4 - Subcontracting) are indeed very important when dealing with construction – they are part of the core business of construction project execution. Most of the other elements can be identified in other elements of ISO 9001 although in some instances this requires some adaptation.

The elements of ISO 10006:1997 that ISO 9001 should accommodate in an explicit way include: project characteristics (element 4); time-related processes (5.5); cost related processes (5.6); risk-related processes (5.11); and subcontracting (5.11.4).

Proposed elements of the main documents of an IMS in construction

The elements of ISO 9001:2000 (quality) were compared with those of the ISO 14001:1996 (environment), of the ILO/OSH 2001 (occupational safety and health) and of the ISO 10006:1997 (project management). For each of these comparisons, some considerations were presented regarding the elements that should be included in an explicit way when dealing with management concerning construction: cost and time, as well as quality, environmental and occupational safety and heath issues.

Based on these considerations, the issue now is to adapt the elements of ISO 9001:2000 by expanding the contents of some of the elements to accommodate or include the important elements that should be explicit.

ISO 9001:2000 should include environmental and occupational safety and health issues by incorporating a few changes that are needed. The first is to substitute the word “quality” with "management", the word "customer" with "client" or, where appropriate, by “client, workers and population”. In this context, the word "client" could also be used with different meanings depending on the area. Concerning the environment the client would be the population or the society, concerning quality the client would be the customer and concerning safety and health the client would be the workers.

Some examples of this adaptation include: the element 4.2.2 would be “management manual” instead of “quality manual”; the element 5.3 would be “management policy” instead of “quality policy” (5.3); the element 8.2.1 would be “satisfaction of client, workers and population” instead of “customer satisfaction”. The proposed adaptations are shown in figure 7 and denoted with * next to the element.

Related to the elements of each standard or guide (ISO 14001, ILO/OSH 2001 and ISO 10006) that should be added, the issue is to decide where they should be integrated in the actual structure of ISO 9001:2000. The proposed integration is shown in figure 7 and denoted with ** next to the element.

In this figure, the hazard prevention and control measure was considered in two different sections of the ISO 9001:2000 modified. The first one was considered in section 5 (management responsibility), under 5.4 (planning) and, more precisely, in 5.4.3 which was called “general hazard prevention and control measures”. The reason for this option is due to the fact that the main concerns on hazard prevention should rely on management responsibility, which has the power and authority to decide the level of prevention that should be considered on each construction project. The second section where hazard prevention was also included is 7 (product realization) under 7.8 (hazard-related processes and control measures) as each construction activity involves hazards that should be identified, assessed and prevention measures taken.

Proposed elements of an IMS in Construction
1 Scope
1.1 General
1.2 Application
2 Normative reference
3 Terms and definitions
4 (~~Quality~~) Management system
4.1 General requirements
4.2 Documentation requirements
4.2.1 General
* 4.2.2 (~~Quality~~) *Management* manual
4.2.3 Control of documents
4.2.4 Control of records
** *4.3 Project characteristics*
5 Management responsibility
5.1 Management commitment
* 5.2 (~~Customer~~) *Management* focus
* 5.3 (~~Quality~~) *Management* policy
5.4 Planning
* 5.4.1 (~~Quality~~) *Management* objectives *and targets*
* 5.4.2 (~~Quality~~) Management system planning
** *5.4.3 General hazard prevention and control measures*
** *5.4.4 Legal and other requirements*
** *5.4.5 Emergency prevention, preparedness and response*
** *5.4.6 Management of change*
** *5.4.7 Management committees*
5.5 Responsibility, authority and communication
5.5.1 Responsibility and authority
* 5.5.2 Management *and worker's* representatives
5.5.3 Internal communication
5.6 Management review
5.6.1 General
5.6.2 Review input
5.6.3 Review output
6 Resource management
6.1 Provision of resources
6.2 Human resources
6.2.1 General
6.2.2 Competence, awareness and training
6.3 Infrastructure
6.4 Work environment

7 Product realization
7.1 Planning of product realization
** *7.1.1 Time-related processes*
* 7.2 ~~Customer *Client-related*~~ Processes related to the client, *the workers and the population*
7.2.1 Determination of requirements related to the product
7.2.2 Review of requirements related to the product
* 7.5.4 Communication with the client, the *workers and the population*
7.3 Design and development
7.3.1 Design and development planning
7.3.2 Design and development inputs
7.3.3 Design and development outputs
7.3.4 Design and development review
7.3.5 Design and development verification
7.3.6 Design and development validation
7.3.7 Control of design and development changes
7.4 Purchasing
7.4.1 Purchasing process
7.4.2 Purchasing information
7.4.3 Verification of purchased product
** *7.4.4 Procurement and contracting, including subcontracting*
7.5 Production and service provision
7.5.1 Control of production and service provision
7.5.2 Validation of processes for production and service provision
7.5.3 Identification and traceability
* 7.5.4 Property of client *and other parts*
7.5.5 Preservation of product
7.6 Control of monitoring and measuring devices
** *7.7 Cost-related processes*
** *7.8 Hazard-related processes and control measures*
8 Measurement, analysis and improvement
8.1 General
8.2 Monitoring and measurement
* 8.2.1 ~~(Customer)~~ satisfaction *of client, workers and population*
8.2.2 Internal audit
8.2.3 Monitoring and measurement of processes
8.2.4 Monitoring and measurement of product
** *8.2.5 Investigation of work-related injuries, ill health, diseases and incidents, and their impact on safety and health performance*
8.3 Control of nonconforming product
8.4 Analysis of data
8.5 Improvement
8.5.1 Continual improvement
8.5.2 Corrective action
8.5.3 Preventive action

* Elements of ISO 9001:2000 that were adapted ** Elements added to the ISO 9001:2000

Figure 7 - Proposed elements of the main documents of an IMS in construction

A final comment is related to the "application" (1.2) as ISO 9001:2000 allows the exclusion of the requirements that do not affect the organisation's ability (limited to those within requirement 7 - Product realisation). In spite of this, for the development of the IMS Manual and the Plan, all requirements should be considered for inclusion at least by level 2 (the 26 elements 4.1 to 8.5) of the proposed structure and where appropriate items should be noted as "not applicable" together with a justification for the exclusion.

5 Conclusions

In this paper a structure for the implementation of an integrated management system in construction was presented and discussed. It attempts to contribute to the discussion on the need for a single methodology to implement the areas under consideration in the construction industry including cost and time concerns. The proposed structure is based on the ISO 9001:2000 elements, taking into account the specific environmental and occupational safety and health issues included in ISO 14001 and ILO/OSH 2001, and also the ISO 10006 on quality in project management. The result is a combination of elements whose contents were extended and others were added to more fully address the needs of the construction process.

Although more work will be done on this subject, it is the author's belief that the benefits that can be achieved with such an alignment warrants an open discussion.

The recent publication of the internationally recognised guide ILO/OSH 2001 to be applied to the implementation of occupational safety and health management systems, together with the other mentioned standards for quality and environment, strengthen the need for this discussion.

The alignment of these standards and guide may have a circular benefit between the areas involved, as the improvement of one will also improve the others due to their inter-relationships. It may also favour the international market and facilitate the growth of relationships between construction companies of different countries, in particular those of the same region, as is the case of the European Union.

It is well known that competitiveness and productivity in construction goes hand by hand. They are key elements for the success of any construction company and construction project. However, it is the author's belief that this is achieved by improving the quality of life of those who will use the constructed product and through better working conditions for those who will build it. After all, people are the most valuable resource in any organisation. The improvement of effective management systems surely helps to achieve these objectives, as they are also a key factor that should not be underestimated.

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Safety oriented time scheduling on the construction site

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Abstract

Italian standards have for several years, for different reasons, called for the development of project management in various stages of the construction process.

Moreover, the new Italian standard concerning Public Works as well as Safety & Health on construction sites now requires the use of project management techniques even for small construction works (approximately 80,000.00 Euro).

However, it is proving hard to find the proper interpretation and position for this planning and management branch of the process, also due to the required standard that is still fragmented and, at times, even cryptic.

This new approach in site management drove the need to implement new tools to help Italian managers and safety professionals, who were used to deal with the building process in a practical, but not organized way.

The paper briefly recounts a study conducted with the aim of structuring the project planning methods and tools needed during the different stages of the construction process, also to allow regulatory compliance.

Keywords

Italian legislation; project planning; construction safety.

1 Introduction

The laws promulgated in Italy starting in 1994 and covering both public and private works and work site safety require the use of typical project management techniques even for small contracts (i.e., worth approximately 80,000.00 Euro).

However, the current situation is still characterized by considerable “resistance” against the application of project management methods and tools within construction processes.

This “resistance” is caused, among other reasons, also in the extreme fragmentation of the Italian construction industry, characterized by companies with very few employees, organized on the construction site according to complex “Russian doll” subcontracting mechanisms by general contracting companies that oftentimes lack the wherewithal to manage them properly.

From the customer's point of view, instead, the lack of focus on the problem of project management is partially due to a lack of knowledge of this discipline's potential.

Aside from the understanding or ability to confront this issue, current regulations – though frequently disregarded – mandate operational and financial planning (which may be updated during the work) involving various professional profiles, in different capacities, during different stages of the construction process.

However, regulations are fragmented and occasionally hard to interpret.

For this reason, a study – briefly presented here – was conducted with the aim of structuring the role of the different professionals involved in the project management of the works and the tools available to them.

2. Italian Standards Background

The planning of the stages of a construction projects or of construction works is basically regulated by the following laws and regulations:

- Law n.109/1994 *Public Works' Basic Rules*.
- D.Lgs. n.494/1996 *UE 92/57 Directive Enactment (S&H on Construction Sites).*
- Law n.415/1998 *Amendments & Integration to Law n.109/1994*.
- D.Lgs. n.528/1999 *Amendments & Integration to D.Lgs. n.494/1996*.
- D.P.R. n.554/1999 *Regulation enacting Law n.109/1994*.
- Regulation concerning S&H Planning on Construction Sites (Draft 2002).

Law 109/1994 lays out the organizational and managerial scenario for all procedures to be followed when planning, designing, executing, testing and managing Public Works. With respect to the construction process design stage, in particular, Law 109/1994 defines three successive levels of detail: the preliminary design, the final design and the constructive design. Each of them entails a different approach to the project management of the specific intervention.

Law Decree 494/1996 is Italy's enactment of European Directive 92/57 concerning the improvement of safety and health in construction site workplaces. The Decree is aimed at achieving this improvement through the introduction of managerial methods and tools referred to the new professional profiles introduced in the construction process (i.e.: S&H Project Supervisor, S&H Coordinators).

Law 415/1998 amends some articles of Law 109/1994, also introducing some new items concerning the instrumentation needed to manage safety in construction sites (introduction into public contracts of the document called Operational Safety Plan, incorporated in the contract).

Law Decree 528/1999 is an evolution of Law Decree 494/1996, both for the construction processes (simultaneous start of the design and safety coordination activities) and in regard to the tools for managing safety (extension of the obligation to prepare the Operational Safety Plan for any kind of construction intervention).

DPR 554/1999 constitutes the Regulations enacting Law 109/1994. Among the many provisions it contains, there is also the description of the precise content of each of the design levels identified by the Law and thus a series of references to the necessary planning tools.

The enabling regulations concerning safety planning in the construction industry, currently available only in draft form, specify the contents of the planning documents and the managerial responsibilities involved.

3. Professional Profiles Involved in Work Planning

The regulatory references set out above require different professional profiles involved in the construction process to develop a planning activity, and specifically, the following:

- (Public) Project Manager (PM)
- Design Manager (DM)
- S&H Project Supervisor (PS)
- Works Director (WD)
- Planning-phase S&H Coordinator (PC)
- Execution-phase S&H Coordinator (EC)
- Site Engineer (SE)
- Site Supervisor (SS)

Each of them, in various capacities, has to produce or deal with the following operational and/or economic planning documents (see Table 1 for a summary):

- Master Plan
- Chrono-programme
- General Works Plan
- Standard Works Plan
- Construction Works Plan
- Production Works Plan

The Public Project Manager, during the initial stage of process, has to determine the duration of the main stages of the intervention, comprising the three design levels (preliminary, final and constructive) as well as the time needed to obtain the necessary authorizations, the time needed for any expropriations and, not least, the time needed to complete the planned works and their testing. These projections must be collected in a general planning preliminary document (Master Plan).

The Safety and Health Project Supervisor (who, in public contracts, coincides with the Public Project Manager) is tasked with the detailed programming of the executive stage of the works, assuming the responsibility (on behalf of the Customer, whether private or governmental) to determine the total duration of the works and to indicate in a Gantt diagram (called General Works Plan) the sequence of the macro work stages and any simultaneous operations allowed by the plan to assure compliance with general safety rules for construction site work.

Note that, for legal purposes, this is a considerable responsibility, entailing criminal liabilities (punishable with up to 6 months prison terms and a fine of up to 4,000.00 Euro).

Table 1

ASSIGNMENT	PROFESSIONAL PROFILE	DOCUMENT
Public Body	(Public) Project Manager	Master Plan
Professionals	Design Manager	Chrono-programme
	S&H Project Supervisor	General Works Plan
	Planning-phase S&H Coordinator	Standard Works Plan
	Works' Director (WD)	Construction Works Plan (works' control)
	Execution-phase S&H Coordinator	Integrated Works Plan
		Construction Works Plan (S&H control)
Contractor	Site Engineer	Construction Works Plan (arrangement)
	Site Supervisor	Production Works Plan

For further proof of the attention given by the legislator to the issue of the congruence of contract time, see the decision shown in Table 2. This document refers to the conviction of a customer (today, Safety and Health Project Supervisor) by the judge who found him co-responsible for a workplace accident caused by the undue haste of the company performing the work (Contractor) to conclude the works to comply with the delivery times imposed by the contract.

Table 2

« *The Customer is responsible with the Contractor for the damages caused by the latter to third parties in the execution of the work when excessively short delivery times are agreed at the time the works are assigned* » (Court of Turin, November 18, 1977, in Riv. Giur. Lav. 1978, IV,151).

The planning duties of the Design Manager are more economical in nature. The "chrono-programme" required by the law pertains mainly to the determination of the progress of the works in relation to the payment dates provided by the contract.

The safety of a construction work site depends to a large extent on the organization and conditions of the work places (internal conditions and/or surrounding conditions) which are continually changed over time. Such changes depend in large measure on the performance of different work in the same place at successive times.

Different work processes may even be conducted simultaneously in the same place. In this case, it is necessary to assess whether the conditions of simultaneity interfere with safety (which would not be acceptable).

Workers' health and safety protection requirements therefore make readily apparent the importance of proper operational planning and of its careful updating during the execution of the work. However, for the reasons set out above, the ability to plan cannot be considered sufficient without the proper sensitivity for the problem of work safety in construction sites.

For this reason, the Standard Works Plan (during the design stage), the Construction Works Plan and the Production Works Plan (during the execution stage), as well as the various work progress audits require the presence, in the construction process, of professionals specifically trained for this purpose, such as the S&H Coordinators, the Site Engineer and the Site Supervisor.

4. Planning Tools

The primary managerial requirement of planning documents is the simplicity of comprehension of their content, which must be able to depict with immediacy the passage of time in relation to the completion of works which can be determined in unambiguous fashion based on their time and spatial positioning.

This ease speeds up the production and operational safety analyses and inspections that will be carried out during the work to monitor work progress.

For this purpose, the levels of the structure of a work plan must therefore be easy to manage from the operational standpoint.

Depending on the type of work plan to be developed, the following four levels of representation may be used.

I Level – Work items

This is a strategic level, because it allows for the possible probabilistic development of operational planning, based on which it is possible to determine the times required to complete a work with a predetermined likelihood of success. It is also useful for the customer to identify the contracts and for a “rough” determination of the potential number of operator who may work on the site.

II Level – Production items

This is the most important level of operational planning. It identifies the individual “production items” of the program, placing them in the spatial coordinates of the construction site's work places.

III Level – Activities

This is a first level of detail, useful for the daily management of life on the construction site. An activity represents a productively structured complex of elementary operations (e.g. carpentry, molds, concrete pouring), which can be analyzed during the design and operational planning stages.

IV Level – Simple Operations

This is a second level of additional detail. It takes into consideration individual construction tasks or elementary operations, for instance the procurement of a pallet of tiles on a slab or the loading of a cement mixer to mix the mortar.

As described schematically in the previous paragraph, operational planning can be formulated (and managed) on different time scales. In general, but not in an absolute sense, the reference time scale depends on the number of successive branches set out by the WBS of the works. In terms of workers' health and safety, in particular, the following planning tools must be used.

General Works Plan (GWP)

This document allows strategic time planning for work site safety. The WBS level to be used is only that of work items, whose unit of measurement of time can be months or quarters (for works of a certain size). The General Works Plan is prepared by the S&H Project Supervisor who has to indicate the duration of the individual work items and their sequence, to avoid interference with safety during their execution. In terms of duration, at this break-down level, one can use the method of the percentage of incidence of manpower on the total price estimated for the item, assigning the number of resources expected to be required to complete it. The critical path of the plan, therefore, is able to define the total duration of the intervention.

In terms of issues interfering with safety, a risk assessment will have to be conducted deciding, for instance, not to allow the simultaneous performance (in contiguous conditions) of other work processes during a demolition or when mounting an elevated steel structure.

Usually, the GWP is a specific attachment to the construction contract.

Standard (Integrated) Works Plan (SWP, IWP)

The development of this document requires considerable effort on the part of the Planning S&H Coordinator. Starting from the progressively produced project documentation, this person has to set out in detail the production items to be associated to the work items identified in the previous level of planning (GWP).

The analysis of production items entails the determination of their spatial placement in the construction site, of the resource load expected for their execution, their duration, their expected sequence (in terms of construction) and their allowable sequence (in terms of work site safety). The unit of measurement of time is usually the month or week for work items and the week or day for production items. Subsequently, for each production item the measures required for injury prevention and workers' protection are studied. These prescriptions will be set out in appropriate sheets of the S&H Coordination Plan (mandated by Law Decree n. 494/1996).

This document is defined as “standard” because it is written during the design of the work, i.e. when, in most cases, the customer and its technical personnel do not yet know the company that will perform the works and its specific operating procedures and production potential. Therefore, the standard works plan contains a forecast of the construction process, obtained by formulating “plausible” work site organizations, based on technical knowledge, to be reviewed, together with the contractor, when the construction contract is executed.

The Integrated Works Plan is a “safety oriented” evolution of the Standard Works Plan as it contains a series of milestones that bind the starting dates of some work processes to inspections, tests, activities, coordination meetings, training and information activities specifically provided for the safety of the construction site. Figure 1 shows an example of an Integrated Work Plan.

Construction Works Plan (CWP)

This works plan is prepared by the Site Engineer on the basis of the indications provided by the Standard Works Plan. In practice, it constitutes the Contractor's concrete operational “reply” to the “plausible” hypotheses developed by the S&H Planning Coordinator. Unless substantial changes are made to production procedures, therefore, the CWP retains the same structure as the SWP, further specifying the duration of work processes and, as the case may be, the operational priorities according to the contractor’s production practice. What should definitely not change, in the CWP, is the structure and the names of the work and of the production items, since they are explicitly mentioned in the S&H Coordination Plan which refers to them to determine the prevention and protection safeguards to be implemented in the productive cycle. For this reason the CWP must receive first the approval of the safety coordinator for the execution stage during the first coordination meeting, before the works are assigned. Usually, the CWP is attached to the S&H Operating Plan (mandated by Law Decree 528/1999 and DPR n.554/1999) prepared by the Contractor.

The unit of measure of time in the CWP, like the SWP, will be months, weeks, or days, depending on whether it is necessary to quantify the duration of a work or of a production item.

Production Works Plan (PWP)

This planning tool is typical of the execution stage of the construction processes. It entails the detailed operational planning (developed on small portions of work to be completed), able to represent with the highest degree of realism achievable even the third level of the structure: the level of activities (on rare occasions, if it is considered particularly useful, it is possible to come down to the level of individual operations). The PWP must be produced by the Site Manager as a technical expert who is perfectly aware of the detailed aspects of the ongoing production process. The time interval covered by the PWP should never exceed two weeks, so it can be constantly updated at periodic work site meetings between the technical staff of the customer and that of the contractor company. The PWP is a very useful tool, for the Execution S&H Coordinator, as it allows for control over any work process interference to be eliminated or corrected, which could not be foreseen during the design stage. The periodic preparation of the PWP also allows the Contractor to meet regulatory compliance requirements pertaining to updates to the works plan during the works for work site safety monitoring purposes (Law Decree 494/1999, A.8).

While clearly the production process of a construction site will never be as precisely timed as in a production line, this type of tool can nonetheless be used to assess even production items or activities destined to last only half a day, in order to provide a clear perception of the progress of production to the Site Engineer and to the Works Manager.

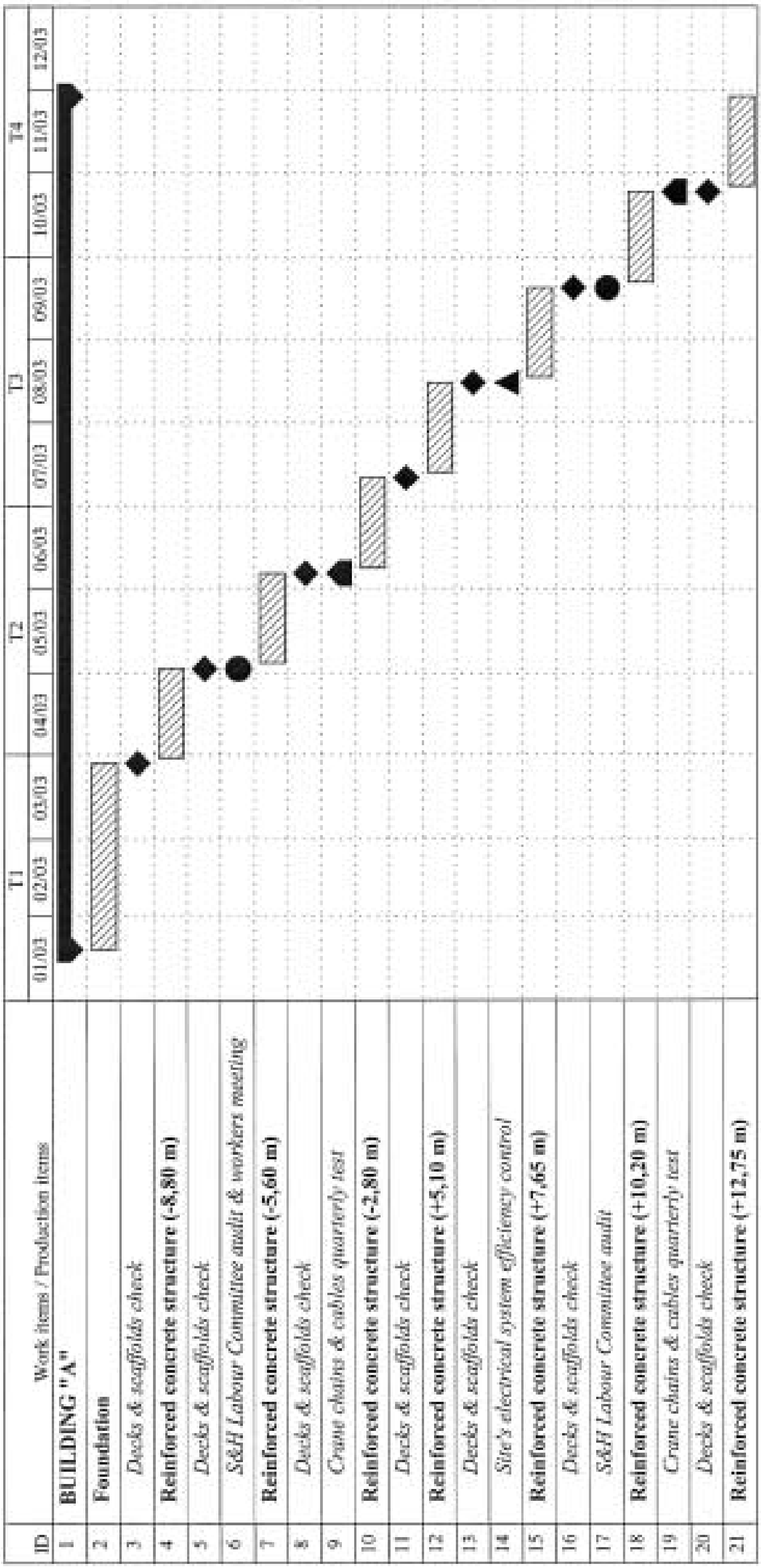

Figure 1 – Integrated Works Plan. Example

5. Conclusions

Introducing project management as a tool to manage contracts, even in the case of works of limited scope, is certain to have a considerable impact on a construction process such as Italy's, which has always been used to "improvise" work sequences "as best as possible", with "imagination".

The advantages brought about by the new regulatory requirements in the construction industry, concerning work planning, cannot yet be translated into concretely quantifiable safety and quality terms. For instance, it is impossible to determine the influence of proper planning on the reduction of work site injuries. In any case, however, there can be no doubt that good safety planning passes through a precise scheduling of the work to be performed.

To the Italian technical community, the negative effects of the lack of planning in a construction process is readily apparent, and more so every day. When the safety of a work process is properly planned, its monitoring generally does not entail production slowdown or disputed situations.

On the contrary, an Execution S&H Coordinator who intends to perform his duties precisely and professionally, in the absence of an adequate work plan, inevitably finds him/herself in the condition of having to "invent" safety day by day, without the support of a real safety plan, of which scheduling represents an essential pillar. And the "daily invention of safety", implying, as it does, a "hiccupping" production process (similar to the periodic succession of non conformities), is certainly no help at all to the quality of the construction process and of the final product.

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Safety and production: an integrated planning and control model

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Abstract

This paper presents a safety planning and control model (SPC) that has been integrated to the production planning and control process. The model integrates safety into three hierarchical levels of production control. Safety long-term planning starts with the Preliminary Hazard Analysis (PHA) of construction processes. These plans are detailed and updated at both medium-term and short-term planning levels. The main performance measure adopted for safety evaluation at the short-term level is the Percentage of Safe Work Packages (PSW). It monitors the degree in which work packages are safely carried out. The model also proposes a participatory mechanism that allows workers to point out existing risks as well as to evaluate risk controls. This paper discusses two empirical studies in which the model was implemented in industrial construction projects.

Keywords

Safety; production planning and control; risk management; performance measurement.

1 Introduction

In Brazil, the main health and safety regulation related to the construction industry is the NR-18 (Work Conditions and Environment in the Construction Industry). Safety planning appears as a core requirement in NR-18, since it is required a health and safety plan named PCMAT (Plan of Conditions and Work Environment in the Construction Industry). However, since NR-18 was established in 1995, most companies in Brazil have produced a PCMAT only to avoid fines from governmental inspectors and do not effectively use it as a mechanism for managing site safety. PCMAT main shortcomings are presented below (Saurin *et al.*, 2000):

a) its implementation is usually regarded as an extra activity to managers, since it is not integrated to routine production management activities. NR-18 does not require its integration to other plans, except for site layout planning;
b) it is usually done by outside experts who do not work on a permanent basis for the company. Production managers, subcontractors or workers are not usually involved;
c) it does not usually take into account the uncertainty involved in construction projects. A fairly detailed plan is produced at the beginning of the construction stage and this is not usually updated;
d) formal control of PCMAT implementation is rarely carried out;
e) it emphasizes physical protections, normally neglecting the necessary managerial actions (for instance, implementing proactive performance indicators) that are needed to achieve a safe work environment; and
f) it does not induce risk elimination through preventive measures at the design phase.

In Europe, Directive 92/57/CEE (Temporary and Mobile Construction Sites) requires a health and safety plan similar to PCMAT (Dias and Fonseca, 1996), which has some of the problems pointed out for PCMAT in Brazil (items *b*, *c* and *d*). Regarding item *f*, although the European Directive requires safety considerations at the design process (especially in product design), this approach has been reported as difficult to be implemented (McKenzie *et al.*, 2000).

Such shortcomings in both conception and implementation of mandatory plans indicate that it is necessary to improve safety planning and control methods beyond what is required by the regulations. In fact, several authors (Ciribini and Rigamonti, 1999; Hinze, 1998; Kartam, 1997) have suggested that safety planning and control (SPC) must be integrated into production planning and control processes, since decision making in both is interdependent. However, few studies have investigated the fully integration of safety into production planning. Ciribini and Rigamonti (1999) and Kartam (1997) discussed the introduction of safety measures into construction plans, using CPM or line of balance planning techniques. This approach tends to have little impact, since it has been accepted that planning should not be limited to the application of plan generating techniques. Planning should rather be regarded as a broader managerial process with several stages, such as data collection, corrective action, and information diffusion (Laufer and Tucker, 1987). Moreover, some of the main requirements for effective production planning and control are also requirements for safety management, such as hierarchical decision making, cooperation, continuity and systemic view (Laufer *et al.*, 1994).

Thus, there seems to be an opportunity for improving SPC methods based on concepts and principles that have been successfully used in production planning and control (Ballard, 2000; Hopp and Spearman, 1996; Laufer and Tucker, 1987). This paper presents a Safety Planning and Control (SPC) model that integrates safety management into the production planning and control process.

2 Research method

2.1 Overview of the research project

Action research was the research strategy chosen for this study to design and test the safety planning and control model in a real construction environment. The first step in the development of the model was an exploratory study to roughly establish the main features and tools of the SPC model. The first empirical study was conducted between January and June 2001, resulting in the first version of the model. The second study was carried out from July to November 2001. Both empirical studies were conducted in the same construction company. The final version of the model was produced after the overall evaluation and discussion of the results of all empirical development phases.

2.2 Description of the company and the sites

The empirical studies took place on the construction sites of a contractor which was chosen for the following two main reasons: it had a fairly well structured production planning and control system, and it was particularly interested in successfully implementing the SPC model. This interest was mainly due to demands from clients of the contractor, who had strict safety requirements.

The construction sites studied were located in the Metropolitan Area of Porto Alegre, in the South of Brazil. The empirical study A was carried out during the refurbishment of a steel mill building (site A in this paper). The empirical study B was carried out during the construction of two laboratories on a petrochemical plant (sites B1 and B2 in this paper). Site B1 consisted of a one-storey building (190 sq.m.) and site B2 was a 2,430 sq.m. three-storey building. High safety risks were primary factors in selecting the three sites analysed. The implementation of the model was co-ordinated by the contractor´s planning and control co-ordinator, who worked in close collaboration with the research team.

2.3 Existing production planning and control process

The production planning and control systems adopted in both sites were very similar. They contained several elements of the Last Planner System of Production Control, proposed by Ballard (2000). There were four planning and control levels: one-day and one-week short-term commitment planning, three-week look-ahead medium-term planning, and long-term planning.

At the short-term level, work packages were assigned to different crews, initially in the weekly meetings. However, due to the variability of the work environment, weekly plans needed to be re-evaluated in daily meetings. The PPC - Percentage of Plans Completed - indicator (Ballard, 2000) was collected both in a daily and weekly basis. The main role of the look-ahead planning level was to support the removal of constraints related to work packages. A three-week plan was produced weekly, containing a list of constraints (e.g. space, materials, labour and equipment), and the deadlines for their removal. Finally, the master plan, including the whole construction project, was updated in a monthly basis.

3 Overview of the SPC model

Figure 1 presents an overview of the SPC model developed in the empirical studies. Integrated safety and production planning and control took place in three hierarchical levels. Long-term planning was developed before starting construction, being updated and detailed at both look-ahead and short-term levels of planning. Safety control involved a set of proactive and reactive safety performance indicators. The results were discussed in a monthly meeting in which a company director was involved. Workers` opinions were taken into account through a risk identification and control participatory cycle. Safety planning diffusion was achieved mostly by training workers based on safety plans before they started carrying out their tasks. In addition to the monthly evaluation meetings, safety performance indicators were also disseminated in weekly planning meetings. Moreover, this information was posted on bulletin boards all over the site.

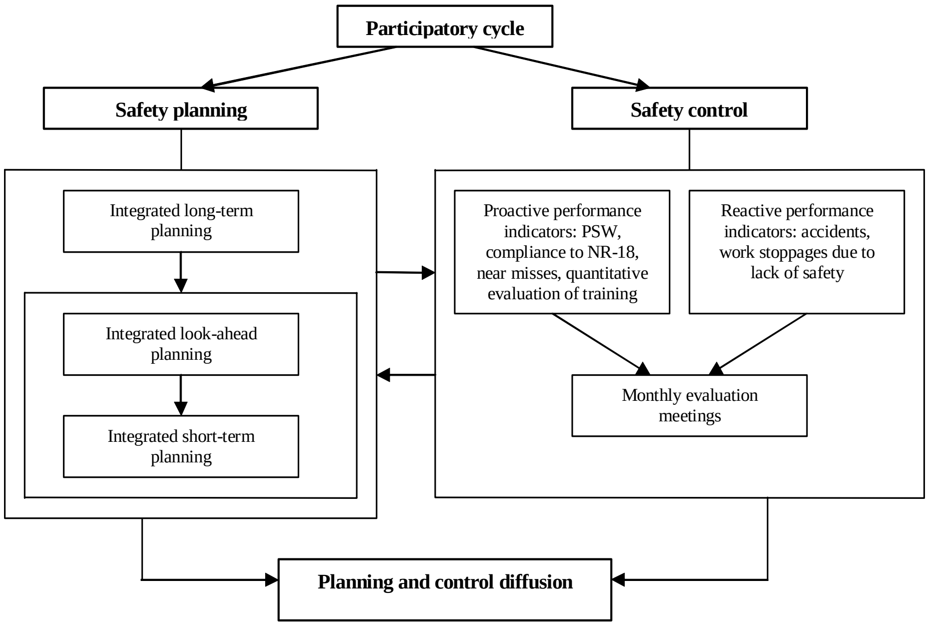

Figure 1. Overview of the SPC model.

4 Development of the empirical studies

4.1 Integration to long-term planning

Long-term safety planning was carried out using the construction phases established in the long-term production plans as a basis. For each construction phase (e.g. bricklaying, roof, etc.) a plan was produced using the Preliminary Hazard Analysis (PHA) technique. In the SPC model, safety plans were categorized into two groups:

a) the first group involved activities whose risks were not always clearly associated to a specific work package. Considering both empirical studies, six plans belonged to this group: temporary facilities (lock rooms and bathrooms), common circulation areas, equipment for materials hoisting, ironwork shop, formwork shop, and mortar production mixer;
b) the second group involved activities whose risks could always be clearly associated

to specific work packages, such as painting, roofing and bricklaying. In both empirical studies, the majority of safety plans were included in this category. In this group, specific plans were produced for families of activities that took place in different construction stages. For instance, since welding activities were performed in different stages, it was easier to devise a specific safety plan for all of them instead of producing several similar preliminary hazard analyses.

A member of the research team was assigned the responsibility of producing the first draft of the long-term safety plans. These were refined through meetings involving a member of the research team and project participants: the site manager, the safety specialist, subcontractors and client representatives. The main steps for producing the safety plans are presented below:

a) establish the necessary process phases to be undertaken: both conversion (for instance, laying bricks on the wall) and flow activities (for instance, moving or storing materials) should be considered, as suggested by Koskela (2000);

b) identify the risks: risks of any nature (e.g. health risks and ergonomic risks) must be considered in each step of the process. In order to establish a common language for all plans, it is also helpful to adopt a risk classification (e.g. caught in, stuck by, etc.) at this stage. In addition, different stakeholders need to be involved, since these may all be valuable sources of information;

c) define how each risk will be controlled: considering that safety control will be based on what has been written down in the plans, preventive measures should not be planned if they are not considered to be necessary or if there are not enough resources to carry them out. Although the aim should be to have no accidents, a contractor will always retain some residual risks, which must be kept within an acceptable level. Managers are the ones who must decide what is acceptable or not, following regulations as minimal requirements.

4.2 Integration to look-ahead planning

Safety constraints were systematically included in the look-ahead constraint analysis, which was carried out weekly considering a planning horizon of three weeks. In this way, safety constraints were formally identified in advance, avoiding stoppages in construction processes. Also, several stakeholders were involved at this planning level: the production manager, the planning co-ordinator, the safety specialist, subcontractors' representatives and a member of the research team. For example, when the safety related constraint ″purchase guardrails components for fall protection system″ was identified, someone was assigned responsibility for the purchase of such item and a deadline was established. The installation of the guardrail was also regarded as a constraint, once a number of work packages should not be started before it.

In both studies, safety constraints were classified into five categories, according to the resources involved: safeguards, personal protective equipment (PPE), design of safety facilities, training and space.

At the look-ahead planning meetings, execution methods were further detailed (in fact, this discussion had begun in the design phase). During the empirical studies, it gradually became clear that this discussion should be undertaken at a fairly detailed level, focusing on the operations performed by workers. This was needed because the stakeholders often neglected the uncertainty related to methods and assumed that teams would know how to carry out the work packages. In an attempt to make this discussion more effective, some questions were systematically introduced in the meetings, such as: How will workers access the workstation? How will safeguards be installed? Where will body harnesses be attached?

Due to the fact that uncertainty is still high, execution methods are unlikely to be thoroughly defined at this planning level. Usually, two or three potentially safe procedures were considered and the final decision was made during the short-term planning meetings. On site testing of alternatives was sometimes used to provide additional information for decision-making.

4.3 Integration to short-term planning

At this level, safety measures were discussed in both daily and weekly planning meetings. The weekly meetings were the most important ones in terms of decision making, since several key stakeholders were involved, including client representatives. Safety and production performance indicators were routinely presented and discussed at these weekly meetings.

Even if formal daily planning meetings do not take place, the empirical studies indicated that some decisions regarding safeguards should be made on a daily basis. This was the case, for instance, of the selection of anchorage points for body harnesses during the replacement of the 300 m length steel mill roof. Such anchorage points had to be relocated daily, according to crew work pace and existing constraints in the facility. If a new risk was identified or risk control measures were changed at short-term or look-ahead levels, this information was used to update the safety plans and to retrain workers. Such changes were documented in a specific form (see example in Table 1), and copies were distributed to the client representatives and subcontractors, during the planning meetings.

Table 1. Form to document changes to update safety plans

Date	PHA nº	Risk	Control
29/03/01	PHA 06	Break energy cables during window demolition *(the cables are inside the building)*	Remove windows from inside to outside

Short-term planning also provided an opportunity to apply one of the core techniques of the Last Planner System, shielding production. This technique recommends that a work package must only be assigned if five quality requirements have been fulfilled: definition, soundness, sequence, size and learning (Ballard, 2000). In this study, safety was considered as part of the soundness requirement.

4.4 Safety Control

4.4.1 Percentage of safe work packages (PSW)

The main performance indicator used to evaluate safety effectiveness, named **PSW (Percentage of Safe Work Packages),** indicates the percentage of work packages that were safely carried out. A work package is considered to be safe when (a) no failure in the conception of safety plans (e.g. unidentified risks) has been detected; (b) there has been no failure in their implementation (e.g. lack of PPE using); and (c) no accidents or near misses have happened. The PSW assessment consists of checking the written safety plans against the actual work being performed – risks that are retained by the contractor are not taken into account in the assessment. The formulae used to calculate PSW is presented below:

$$PSW = \frac{\sum \text{number of work packages safely carried out}}{\sum \text{total number of work packages}} \qquad 4.1$$

It must be also emphasized that a work package will be only considered as 100% safe after it has been completed. By definition, accidents are unplanned and uncertain events. Then, there is no total guarantee that accidents will not happen, even though all planned safety measures have been implemented. Table 2 schematically presents the form used to collect data for calculating PSW in the empirical studies. Similarly to the Last Planner System, an analysis of the causes of safety planning failures must be conducted - a checklist for classifying such causes was developed to facilitate this task.

Table 2. Example of form used to collect data for calculating PSW.

Site: Steel mill refurbishment	**Observer**: Diego		**Date:** 10/05/01		
Observation period: 10h to 12h			**Safe?**		
Gang	**Work packages**	**PHA nº**	**Yes**	**No**	**Problem**
BSF	Walls from column 25 to 28	PHA 2	X		
SH	Change roof from column 5 to 7	PHA 5		X	Body harness badly tied
	Activities not clearly associated to work packages				
BSF	Common circulation areas	PHA 8	X		
BSF	Formwork shop	PHA 6	X		

If possible, this indicator must be collected on a daily rather than on a weekly basis, because some safety problems can be only identified through careful and frequent observation of site activities. Unlike PPC, PSW calculation takes into account activities that are carried out even if they have not been identified in production plans. Moreover, work packages that have not been initiated are not considered in PSW calculation, unless the cause for not carrying them out was the lack of safety. The main steps for collecting PSW data are presented below:

a) define the work packages in the weekly or, preferably, daily plan, and write them down in the second column (first section) of the PSW form;
b) list the activities not clearly associated to work packages in the second column (second section) of the PSW form;
c) write down the identification number of the safety plan(s) related to each work package or to the activities not clearly associated to work packages, in the third column of the form;
d) walk around the construction site and identify where each work package is being carried out. Observe how the activity is being performed, checking whether the safety measures listed in the respective PHA are being implemented. The observer must also pay attention to identify any other safety related event not specified in the PHA (for instance, a risk not identified in the PHA). The length of time dedicated to each observation varies according to a number of factors, such as the size of the crew, the complexity of the task and the work environment. In the empirical studies, the typical period of time dedicated to observe each work package was around fifteen minutes;

e) if an activity not scheduled in the production plans is observed, it should be regarded as a new work package and included in the form. If there is a PHA for that activity, this is the basis to evaluate whether the work package is safe or not;
f) calculate the daily PSW and conduct the failure analysis. The form should only be completed at the end of the working day, since other safety failures can be detected after the observation period.

4.4.2 Other control measures

Besides PSW, other performance indicators were also monitored. Some of them were related to the impact of the lack of safety, such as the number of accidents and delays that resulted from work stoppages caused by safety failures. However, in this research project emphasis was given to controls that had a preventive character. In this respect, two proactive indicators were proposed: (a) the degree of compliance to NR-18, evaluated through a checklist; and (b) the ratio between the number of man-hours of training and total number of man-hours. The documentation and investigation of all near misses was another important preventive measure. Near misses were reported by safety specialists and by PSW observers.

The results of all performance indicators were presented in a report, which was discussed in a monthly evaluation meeting. Four of those meetings took place in each empirical study, involving a company director, the production manager, the safety specialist, the planning co-ordinator, an outside safety expert and a member of the research team. As the main result of each meeting, an action plan including both preventive and corrective safety measures was produced.

4.5 Workers participation

Workers should take an active role in the SPC process, since they are its main customers and beneficiaries. In order to get them involved, the SPC model proposes a cycle of risk identification and control based on workers perceptions, as illustrated in Figure 2.

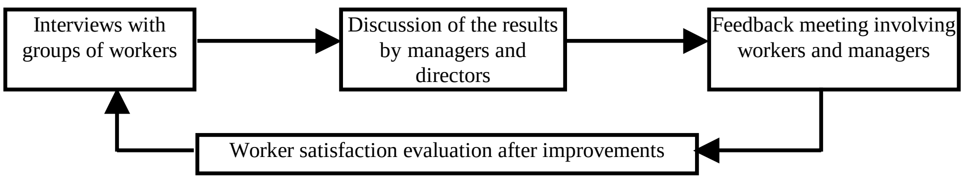

Figure 2. Risk identification and control cycle based on workers perceptions.

The **first stage** involves interviews with small groups of workers, typically eight. The interviews aim to identify new risks and to evaluate the effectiveness of existing controls. They are divided into two stages: (a) an open section, in which workers are encouraged to talk not only about the tasks performed by them, but mainly about both good and bad aspects of their work, and (b) an induced section in which workers are asked to talk about predefined issues, such as manual material handling, awkward postures and PPE. When a problem is reported, workers are asked to suggest ways to solve it.

The **second stage** consists of discussing the results of the interviews in a meeting involving production managers and a company director. In this meeting, the first draft of an action plan to solve the problems reported by the workers is established. The **third stage** consists of a meeting involving both workers and management. The action plan is presented by management and discussed with the workers. Finally, the **fourth stage** aims to evaluate worker satisfaction after the improvements have (or have not) taken place. This evaluation is based on another group interview, in which new risks can be identified and controls are re-evaluated. No strict interval between interviews has been proposed in this study. However, new interviews should be carried out when a substantial number of new teams come into the site. Two risk identification and control cycles took place in each empirical study.

5 Main results

5.1 Safety performance indicators

Considering both empirical studies, two accidents with working day losses and twenty-one near misses were registered. Moreover, in the first empirical study there were three situations in which tasks did not take place due to safety planning failures. The PSW indicator was collected in all three sites. Since the data collection procedures were not sufficiently mature at the time of the first study, members of the research team carried out this task. In the second study, the safety specialist contributed with 21.5% of the data. While the safety specialist did not assign a specific amount of time to collect data, the researchers spent between one and two hours a day on this activity. As an illustration of the results, Figure 3 presents the evolution of PSW and PPC on site B1, where data was collected from the beginning to the end of the project.

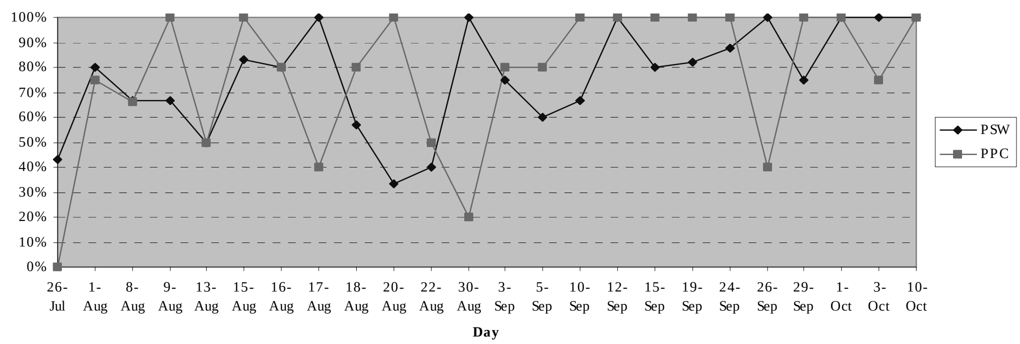

Figure 3. Illustration of PSW and PPC results (site B1).

In this example, two trends appear to exist after the project was 50% complete: both PPC and PSW increased, and there was a reduction on the variability in both of them. This reduction indicates that both production planning and safety planning became gradually more reliable.

Figure 4 presents the causes of safety planning failures in site A, where failures in safeguards planning were the main problem. Many problems have been included in this broad category, such as the lack of isolation of areas under scaffoldings, and the lack of support for ladders.

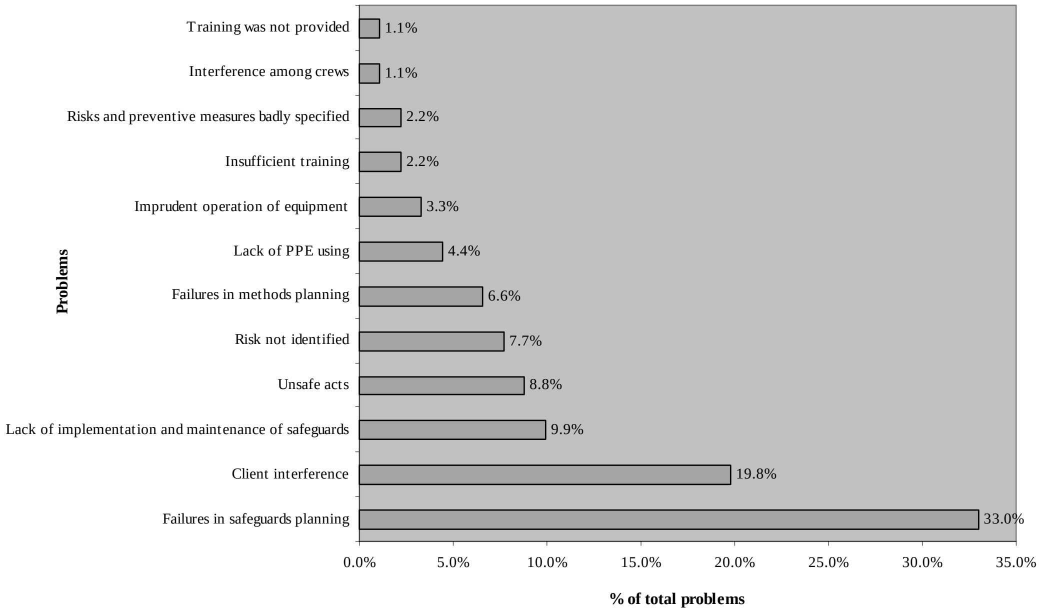

Figure 4. Causes of safety planning failures (site A).

5.2 Workers´ perceptions on safety

As an example of workers´ perceptions on safety, Table 3 presents the partial results of the first round of interviews in the empirical study A. All demands were classified according to their nature: work environment, including issues such as noise and lighting rates; design of processes and work stations; human resources; personal protective equipment, and training.

Table 3. Main problems according to workers (first round of interviews in the empirical study A).

Problems	Type
1. Widespread dust	Work environment
2. Lodges are untidy and dirty	Human resources
3. Body harnesses do not fit properly	Personal protective equipment
4. Two cable body harnesses are necessary to work on scaffoldings	Personal protective equipment
5. Poor quality rubber gloves	Personal protective equipment
6. Workers were assembling scaffoldings without previous experience	Training
7. Lack of knowledge on steel mill risk areas (where am I not allowed to walk?)	Training
8. Access to the steel mill bathroom is risky	Training
9. Horizontal transportation distances are too long (layout problems)	Process and workstation design

6 Conclusions

This paper presented a safety planning and control model (SPC) which was developed through two action research empirical studies, carried out in industrial construction projects. Differently from previous proposals to integrate safety into planning, which focused mostly on the development of safety plans, the SPC model takes into account the control function and regards safety planning and control as a broader managerial process. The results indicated that several concepts and methods successfully used in the Last Planner System (such as constraints analysis, shielding production and planning failure analysis) can be easily extended to safety management. In fact, the implementation of the SPC model requires the pre-existence of a production planning and control system, which contains some key elements of the Last Planner System: hierarchical decision making levels (typically long-term, medium-term and short-term), constraint analysis, planning meetings on a regular basis, and assignment of work packages based on quality criteria.

In addition, a hierarchical decision-making process on safety measures was established, involving client, managers, subcontractors and the workforce. The Preliminary Hazard Analysis (PHA) technique was used for producing long-term safety plans, being continuously updated and detailed through the integration of safety into look-ahead and short-term planning levels. In this way, safety planning and control was systematic and continuously applied during the whole project.

A systemic approach to SPC was adopted, since the model involves a set of inter-related tools and procedures. The analysis of causes of safety planning failures was also systemically approached, as the aim was to identify the underlying causes of unsafe acts and unsafe conditions. In this respect, planning and control failures were identified as major causes of the lack of safety.

The SPC model might potentially constitute a key element of a broader health and management system based on BS 8800 standard (Guide to Occupational Health and Safety Management Systems), since it is established a formal safety planning and control cycle. A contractor could use the elements of the SPC model as a means to comply with major requirements of BS8800. For instance, the performance indicators could be used to comply with the performance measurement requirements proposed by BS8800.

7 References

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Quality Management System Certification in Small AEC Organisations: a Strategic Choice or an Obligation to Meet Customers Requirements?

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Abstract

The implementation of a Quality Management System (QMS) in Architectural, Engineering and Construction (AEC) organisations can constitute a voluntary and strategic decision, but can also be the result of an “external pressure”, made by customers, which brings the organisations towards certification.

The major objective of this paper is to discuss the decision-making processes concerning the strategies of implementing a QMS in very small AEC organisations, of less then 10 collaborators, in order to orient the development of the so-called “professionals” certifications, by their different associations. We discuss it faced to both the Brazilian and the French realities.

The major conclusion is that the forces can lead to four types of decision-making processes and not only to two, as defined by Shapero’s conceptual framework (Shapero & Sokol, 1982).

In the situations where the approach is totally voluntary, firms develop a *proactive strategy*. It is the *strategic vision* of the leader that plays the most important role: he must consider that the certification could be a means of constituting a competing advantage; his perceived *desirability* must be strong.

In the situations in which the organisations are “obliged” by the customers to be certified, they develop a *reactive strategy*, almost obligatory. It is the *event* or the *break in the established routine*, represented by the conditions imposed by the clients, which drives organisations towards certification.

Nevertheless, between these extremes situations, we can define a third one, also *proactive*, but associated with *event* that will play an important part in the passage of the *intention* to the *behavior*, but represented by the professional certifications and by the support offered by the professionals unions.

Finally, the last model is the extension of the second one, where the certification is “*quasi-obligatory*”.

Keywords

Small enterprises; quality management system; professional certification; strategy; AEC

1. Presentation and the importance of the small enterprises

Many papers show the importance of the implementation of a Quality Management System (QMS) in Architectural, Engineering and Construction (AEC) firms to afford problems concerning the lack of quality in construction. Nevertheless, feel of them analyse this question by two crossed points of view: the size of the firm and the perception of its top manager, normally the owner him/herself, of the strategic character of a QMS.

In Brazil, medium-sized enterprises of the tertiary sector are those of less than 50 collaborators and the very small ones of less than 10 (these values are 100 and 20, in the case of the industrial sector). In France, the *Institut National de la Statistique et des Etude Economiques* (*INSEE*) considers as small and medium enterprises those having between 10 and 499 employees, considering those having more then 200 as "large-small and medium enterprises". According to the Organisation for Economic Co-operation and Development (OECD), the very small enterprises (VSE) are those which less then 20 employees, and the "micro" ones those which less than 10.

Any way, the role of the small and the very small enterprises in the economy is eloquent. For example, according to the *Serviço de Apoio às Micro e Pequenas Empresas* (*SEBRAE*), organisations of less than 49 people represent in Brazil 98% of the 3.5 million firms and 35 million employees. According to the *INSEE*, the organisations of less than 10 collaborators represent in France 92% of the 2.6 million organisations.

In many countries, mostly of the architectural and engineering firms are small or very small-sized, as far as the subcontractors on even the contractors. For instance, in the UK, 96% of the 180,000 construction firms have less than 8 employees; 86% of the employees work within small and medium firms, which are responsible for 75% of the turnover (Jaunzens, 2001). In France, 95% of firms of the building sector have less than 500 collaborators, representing 1.1 million employees and 60% of the turnover (*INSEE*).

Even if several studies treat small and medium-sized enterprises, there are few dedicated to the very small ones, developing and implementing QMS. Publications like Standards … (2000) and ABCB (2001) deal with the applicability of the ISO 9000:2000 standards in small organisations, and are nevertheless generic.

In this context, the major objective of this paper is to discuss the decision-making processes concerning the strategies of implementing a QMS in very small AEC organisations, of less then 10 collaborators, in order to orient the development of the so-called "professionals" certifications, by their different associations.

It is based on a theoretical research, complemented by field observations, made in Brazil and in France, mainly interviews made with consultants, member of professional's associations and of certification bodies.

2. The Brazilian and the French "professionals" certifications

As presented on Cardoso *et al*. (2000) and on Cardoso *et al.* (2001), the construction sector in Brazil, and in particular the housing sector, involving the majors public and private actors, is conducting a very important national program witch aims to improve quality, productivity and innovation, the Brazilian Quality and Productivity Habitat

Program (*PBQP-H*). It is an evolution of *QUALIHAB Program*, of the State of Sao Paulo's Housing and Urban Development Company (*CDHU*).

The development and implementation of new forms of QMS is one of the bases of these Programs, thanks to "professionals" certifications, specifying requirements, based on the ISO 9001 standard, adapted to each actor directly concerned.

The *QUALIHAB Program* has already implemented QMS standards concerning: general contractors, construction managers firms, geotechnical subcontractors, and geometricians. Architectural and engineering enterprises are not concerned up to now. The *PBQP-H* has already implemented a QMS standard concerning general contractors; the architectural and engineering firms' ones will be implemented in 2003. Up to December 2002, *PBQP-H* general contractors' certification *SiQ-Construtoras*, based on ISO 9002:1994, has already certified 1,568 firms.

We can find in France the same kind of approach, conducted by the professional associations, witch resulted in standards like: Qualibat (general contractors and subcontractors), MPRO Architecte® (Architects), QUALIMO® (social housing managers) QUALIPROM® (real state firms), Référentiels de Services CAPEB (small subcontractors), and Entreprise Générale de BTP (huge general contractors).

Nevertheless, there is a very important difference between Brazilian and French experiences: in Brazil, the professional certification is almost obligatory, as the public clients start more and more to define them as an obligatory criterion in procurements. Moreover, the private building owners are constrained to call upon certified general contractors to have financings of the most important Brazilian Housing banks, Caixa Econômica Federal, Bradesco, Itaú and ABN AMRO Real.

3. The QMS certification as a strategy of the organisation

A certification according to the ISO 9001 standard constitutes to an organisation a "strategic basic immaterial investment" (Messeghem & Varraut, 1998). Nevertheless, the top manager has not always conscience of this strategic role, especially in very small organisations, when he/she is "obliged" by the customers to be certified, having a "reactive" comportment. This is true even though the International Standard says "*The adoption of a QMS system should be a strategic decision of an organisation*."

Any model representing the decision-making processes concerning the strategies of implementing a QMS must take into account the situations where this is done in a voluntary or in a reactive way. According of Shapero & Sokol (1982), the conceptual framework justifying the implementation of a certified QMS by the top manager of a small organisation has three major points:

- the *strategic vision*, or the mental representation of the leader, of the present and of the future of his/her organisation and of the environment;
- his/her *strategic intention* to adopt a behavior;
- his/her *proposed behavior*, or the strategic action itself, represented for example by an engagement towards a professional certification.

The leader choice will still depend of four others elements:

- his/her *perception of feasibility*, or his/her perception of his/her capacity to carry out in the long term and successfully a project, the certification, which is integrated in his/her strategic vision (the perception of his/her control over the behavior);

– his/her *perception of desirability*, which is connected with the perception of his/her desire to see succeeding his/her project;
– his/her *propensity to act*, which characterizes a feature of personality relating to the dynamism of the leader and thus to his/her capacity to achieve his/her objectives;
– the *break* or the *event*, which is perceived as been determinant by the leader, pushing him/her to act.

By combining these seven elements, Messeghem & Varraut (1998) have created two models of behaviour of the process of implementing a QMS, which "*must be perceived as the ends of a continuum*". The first one (Figure 1a) represents the *proactive strategy*. As the name suggests it supposes an action started by the leader him/herself:

"*The strategic vision of the leader will play a very important role. If the leader considers that the certification may be a competitive advantage, his/her desirability will be strong. His/her perception of feasibility will not play an important part as he/she will tends to consider being able to conduct the process. In certain cases, the leader can even have the tendency to elude the organisational or financials risks… One is likely to observe a strong propensity to act, in particular when few organisations are implementing the process … The event will not play an important part in the passage of the intention to the behavior. The contractor does not await an explicit message of the environment to start the process of certification. Quite to the contrary, he/she anticipates it. He/she is attentive to the environment; he/she does not hesitate to play an active part in the professional organisations to have information and to create a relational network.*"

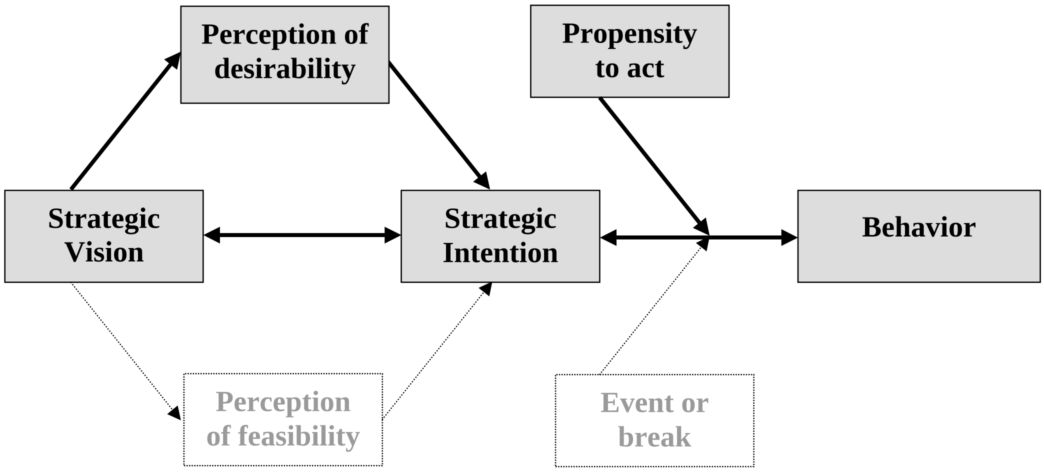
Once achieved, the ISO 9001 or the professional certification will constitute a differential recognized by the customers, and the organisation profits to create a competing advantage. It can also represent a means of improvement its performances, thanks to a better organisation and to a more efficient management. That offers more chances to the organisation to make profits, and also the possibility of offering more competitive prices.

This is the ideal situation concerning professional certification, but rather rare in very small organisations, when the reactive strategy (Figure 1b) constitutes the more typical case:

"*When the leader adopts a reactive attitude, the strategic vision and the strategic intention do not seem to play a determining role. The event is decisive to the decision-making process and it can be represented by a hardening of the conditions of purchase imposed by customers, in particular concerning quality management. The leader must then act if he/she wishes to ensure the continuity of his/her organisation. His/her margin of freedom is much weaker. His/her perception of desirability can be influenced by the event. For example, a certified competitor can encourage the leader to launch out in this way… His/her perception of feasibility will not play an important part in the decision-making process. Indeed, it is not a question, for the leader, of knowing how to answer to these new requirements. Propensity to act (or to react) is low in the absence of a précipitatif event and becomes strong in its presence.*" (Messeghem & Varraut, 1998)

Nevertheless, we don not think that these two cases represent the reality of the building sector. It is missing two more models, one of them being mainly valid for Brazil. They have both very strong bonds with the implementation of professional certifications.

a) Proactive strategy:



b) Reactive strategy:

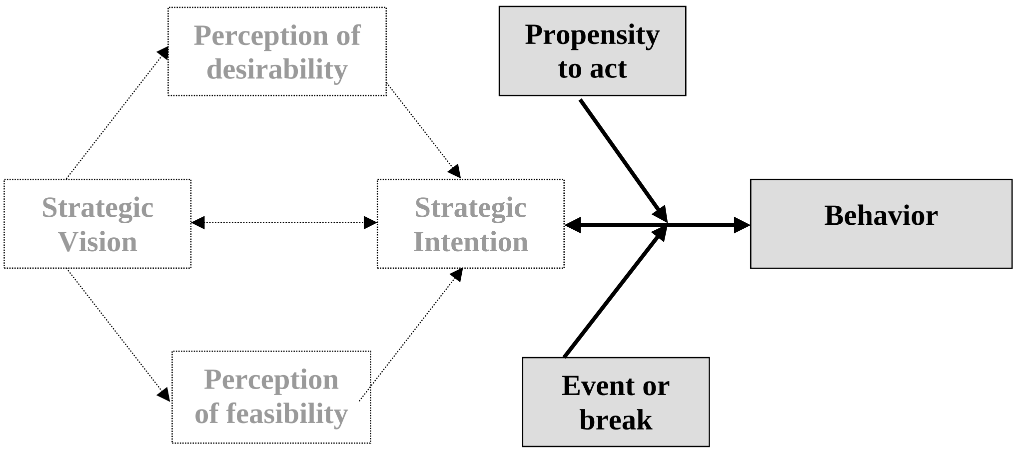
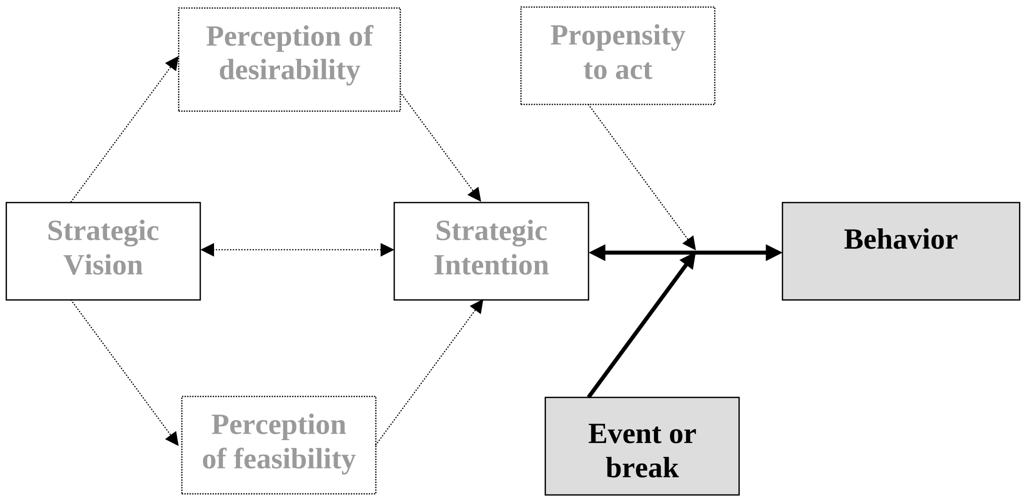


Figure 1 - The decision-making processes concerning the strategies of implementing a QMS: the two models of behaviour proposed by Messeghem & Varraut (1998).

Nevertheless, we don not think that these two cases represent the reality of the building sector. It is missing two more cases, of which one is mainly valid for Brazil. They have both very strong bonds with the implementation of professional certifications.

As show in chapter 2, in the building sector in Brazil, the professional certification, an important précipitatif *event*, has almost become an obligation in building. This suggests the creation of a third extreme model of behavior, the "*quasi-obligatory*" one, as seen in Figure2c.

c) Reactive strategy, “quasi-obligatory”, due to the market forces:



d) Proactive strategy related to professional certifications:

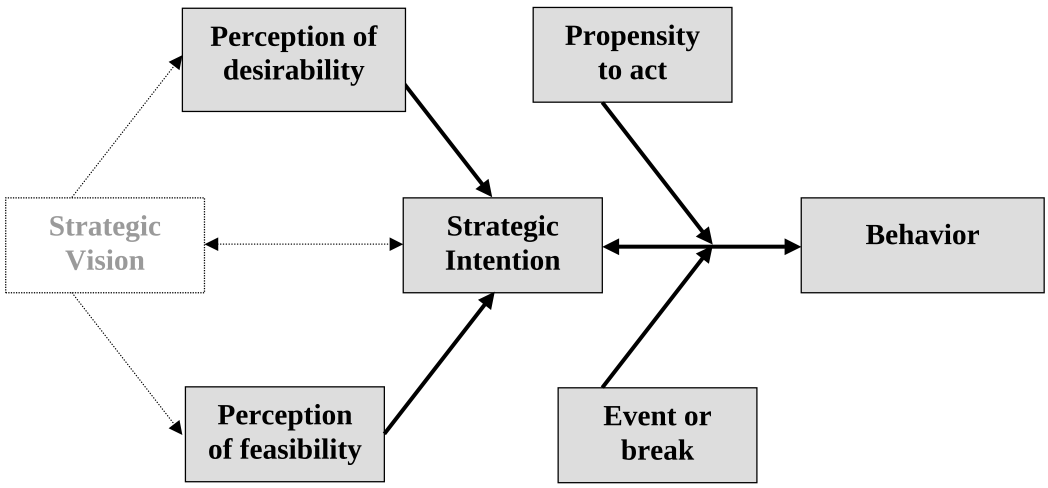


Figure 2 – Two decision-making processes concerning the strategies of implementing a QMS: two specific models of behaviour valid to the building sector and made possible thanks to the professional certifications.

Ofori & Gang (2001), while speaking more specifically about realities in Malaysia and in Hong Kong concerning public markets, have said:

> *“The mandatory requirements that large contractors must be ISO 9000 certified before they can register to undertake public-sector projects should be viewed as client pressure (rather than regulation) as it relates to procurement (i.e. prequalification). QMS certification is not compulsory; firms wishing to work only for private clients or on projects valued at less than S$30 million do not need to be certified.”*

Nevertheless, and mainly in France, but more and more also in Brazil for private markets, the three modes continue not to be sufficient to represent what occurs in the building sector. That is true even if voluntary engagement on QMS certification constitutes in France one of the major principles of procurement.

In fact, concerning very small organisations, the “voluntary” comportment of the *proactive model* can be incited by actions carried out by the professional unions and by certain establishments that give support to the small organisations. These actions, essential for the success of professional certifications, concern more particularly the leader’s *perception of feasibility* and the *perception of desirability*; they create, also, a précipitatif *event*. Moreover, they constitute means of articulation between the *strategic intention* and the proposed *behavior*, increasing the *propensity to act*, even thought the leader has not a *strategic vision* (Figure 2d).

The professional unions must nevertheless take care to make so that the top manager do not develop a false *strategic vision*, by believing that the clients will give a bigger weight to certification and will support in their choice the certified organisations. Notwithstanding, these unions must act near the public and private clients, to make them known de benefits of the professional certifications.

Professional certifications, written on the organisations’ “language”, offer the best conditions for the implementation of a QMS, encouraging VSE’s top managers. It is essential that the leaders of the very small organisations recognize themselves on the certification, so that the *perception of feasibility* replaces the *strategic vision*, rare in this kind of manager; the certification process of the organisation must be very clear for him/her, to ensure its success.

To help the VES, the professional unions have to offer a broad range of services of voluntary engagement: continuous training; follow-up activities; orientation to the organisations to find funds to finance their actions, etc. Thanks to these initiatives, the professional unions seek to affirm the capacities of their associates near the customers and other agents of the supply chain. This is particularly true in France.

Nevertheless, the Brazilians’ VSE still suffer of the lack of actions adapted to their characteristics, even if certain Brazilian establishments which give support to them are making complementary actions, like the *SENAI* and *SEBRAE*.

A common characteristic in Brazil and in France is to work in networks, developing co-operative relationships between firms, sharing experiences, which is very enriching. The professionals unions create these nets, mainly during training and the accompaniment of the implementation of the QMS. This practice permits an economy of resources and the development of competitive advantages, dues to the access to new knowledge concerning managerial practices, skills, procedures, market requirements and strategic choices made by the firms. The managers, as members of networks, share their experiences, the commitment is greater and the uncertainty is reduced.

This approach also makes possible the implementation of the system in a less “theoretical” way; the direct implication of the top manager, especially of the VSE, decreases the risk of a typical phenomenon: “the consultant that only adapts his/her standard tools and procedures to the organisation”.

Another very important feature, especially in VSE, is the commitment of the personnel. The whole of the personnel of the organisation must be federated around the implementation of the QMS. The lack of implication has several risks: disengagement with respect to the system, reduction in the motivation, “sabotage” of the system, etc.

A second point: the quantity and the quality of documentation. The documentation of the QMS must be written without too much charging the organisation and considering its know-how. That is more crucial as the professionals of the building sector have an oral tradition. The development of professional certifications inspired by the ISO 9001:2000 standard is one of the solutions.

The financial incentives are also an important incentive to a “voluntary” professional certification, in particular to the very small structures, whose resources are almost always limited.

An argument, which still remains to be developed, relates to the financial advantages of the implementation of a QMS. Does it bring real economies more important than the expenses of the implementation and operation of the system?

Like it announced Arditi & Gunaydin (1997):

“*A survey of US firms indicates that the major obstacle to using the ISO 9000 standards is the additional cost of modifying work procedures and the additional cost of revising standard.*”

Nevertheless, we share the vision of Patrick Nossent on this subject (AQC, 2001):

“*For what to transfer the burden of proof and to require demonstrations attesting the financial advantages of the QMS? Does one ask for the same thing when an organisation sets up a new information system? And investments in data processing, can one quantify the profits that they bring? And those of a training policy?*”

4. Conclusions

To conclude, Figures 1 and 2 show the decision-making processes concerning the strategies of implementing a QMS in very small AEC organisations, according to a *proactive* strategy or to a *reactivate* one, in *voluntary* or *obligatory* matter, pushed by elements like the *perception of feasibility*, the *perception of desirability*, the *propensity to act* and the précipitatif *event*.

We have shown the importance of professional certifications in these processes, as far as two of the four of the decision-making processes concerning the strategies of implementing a QMS by top manager are directly related to them.

It is legitimate to suppose that the level of effectiveness of the QMS drops when the organisation passes from the mechanism “*proactive volunteer*” to the “*quasi-obligatory*”. That is the case in Brazil (Cardoso et *al.*, 2001) and in Malaysia and in Hong Kong (Ofori & Gang, 2001). The importance of this phenomenon becomes greater when the size of the organisation decreases: the smaller the organisation is more the voluntary approach becomes essential. Once again, the professional certifications have a fundamental role to play.

The development of the professional’s certifications, by their different associations, must take in consideration these roles, as they are doing in Brazil and in France. The balance between the complexity of the assessment requirements and the motivation of firms (*propensity to act*) is a major point that must be considerate in the development of such kind of certification: they must be attractive to customers and to organisations, mainly to small ones.

We share the vision of Messeghem & Varraut (1998) of for pragmatic nature, operational and not only strategic, of the decision of a manager of going towards certification:

“*Certification of organisation can correspond to an important dimension of the strategic vision, but also to constitute a means to materialize the strategic intention.*”

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The implementation of occupational health and safety management systems in one construction company in Brazil

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Abstract

The purpose of this work is to present a methodology for implementation of an Occupational Health and Safety Management System in a construction company, based on OHSAS 18001 - Occupational Health and Safety Management Systems standard requirements. The implementation leads the company to an occupational health and safety performance improvement through the hazard elimination or risk control, workplace health improvement, and a better relationship with workers, trade unions, clients and regulatory bodies.

The methodology developed was applied in one building construction company in the State of São Paulo – Brazil and led the management system to a certification by an international registration body. This paper presents also the preliminary results obtained due to this methodology application that can be well suited to construction companies of other countries.

Keywords

Occupational Health and Safety Management Systems; construction safety; construction

1 Introduction

The accidents occurred recently and divulgated by the press, like petrol leaking, explosions, land slipping and others make clear that the companies must adopt an ethical and responsible posture, respecting the environment and the workplace conditions.

The OHSAS 18001 - Occupational Health and Safety Management Systems (1999) have been developed in response to urgent customer demand for a recognizable occupational health and safety management system.

This standard intends to be unique, internationally recognizable and applicable to any kind and size of organizations and against which their management system can be assessed and certified.

The implementation leads the company to an occupational health and safety performance improvement through the hazard elimination or risk control, workplace health improvement, and a better relationship with workers, trade unions, clients and regulatory bodies.

This work presents a methodology for implementation of an occupational health and safety management system in a building construction company that has been developed in response to customer demand of Brazilian companies. It was developed through researches such as detailed studies of management system standards, four surveys with certified industrial companies, experience of this author as quality systems consultant and mainly through the implementation of it in one building construction company, which preliminary results are presented in chapter 3. It does not present the results of the studies concerning management system nor the surveys with certified industrial companies.

This pioneer methodology is an important contribution to the sector in Brazil even if the studied building construction company is not the first one to be certificated by OHSAS 18001 in this country.

2 The developed methodology

2.1 General Structure

The methodology consists of a list of tasks that are intended to be carried out by the construction company in a logical sequence allowing a progressive and organised implementation of the management system.

Each task contemplates one or more OHSAS 18001 requirements, thus when the company complies all the tasks proposed the standard requirements are immediately fulfilled.

The first step is the creation of an implementation work group, which will be the manager of the methodology implementation process.

This group shall include de following members of the organization: safety engineer, construction and project manager. They will spend some time in the implementation process, so they must be committed to the system and to continual improvement.

Such group shall establish an implementation plan, which must take in consideration the size of the company and the available financial resources and staff.

2.2 Task 1 –Health and Safety Policy

It is known that the actions that focus on the workplace safety and health are well succeeded when they flow from the top to the bottom in an organizational structure, therefore, the top management shall draft and authorise a policy that clearly establishes a general aiming of the company, as well as the principles of its actions.

According to HAMER (1985), a primordial requirement for any successful program is not to leave doubts for any one of the employees that the top management is engaged in the prevention of accidents.

Moreover, the top management has moral and legal responsibility for the maintenance of workplaces in safe conditions, or either, in conditions favourable to the health and the physical integrity of the organization employees.

It can be said that the H&S policy is a letter of intentions that shall have the topics that will be effectively followed by the organization and can be clearly evidenced (Figure 1).

A policy shall contain, at least, commitments:

- To provide an safe and healthful workplace;
- To continual improvement; and
- To at least comply current applicable occupational health and safety legislation and other requirements subscribed by the construction company.

Safety and Health Policy **Hypothetical Construction Company is committed to:** Keep the workplaces safe and healthy Comply the legislation and other requirements applicable Provide all necessary training Continuously improve its processes through safe technologies

Figure 1. Example of a Safety and Health Policy

2.3 Task 2 - Legislation and other requirements

The construction company shall do a research to find out all applicable occupational health and safety legislation and other requirements to which the company subscribes.

This research can be done by the following ways: Internet researches, contracting specialised companies, contacting regulatory bodies and trade unions, surveying books and other publications. The company shall obtain all necessary documents creating an indoor legal library.

After that, the implementation work group shall carry out a review of each document, taking note of all topics that are applicable to the company, but are not complied by it. This review could require some consultation to regulatory bodies or even though contracting specialists' services.

For every topic not complied by the company shall be established action plans (Figure 2) that detail all necessary activities, responsible and time limits to comply them.

The implementation work group shall also establish a procedure to keep this research updated and to assure that obsolete documents are promptly removed from all points of use.

Document	Topics not complied	Action Plan		
		Necessary activities	**Responsible**	**Time Limit**
Fire department regulation Number 18 – November 1977	18.4.1 Lower number of fire extinguisher	Acquire four new fire extinguisher	Wilson	10 days
		Install the fire extinguisher in the work site	Wilber	15 days
		Review and revise the fire prevention procedure	William	20 days
...	...	...	...	...

Figure 2 – Example of an action plan

2.4 Task 3 – Hazard identification and risk assessment

The construction company shall identify all activities, workplaces and equipments inside the scope of the H&S management system. It shall include construction activities (masonry, demolition, roofing and others), handling and material storage, equipment operation, maintenance activities and office activities. Activities conducted by suppliers and subcontractors inside the work site are also concerned.

After that, implementation work group shall create work groups to identify all hazards related to activities, workplaces and equipments previously identified. Such task shall include arrangements to involve and consult the employees or its representatives.

Identified hazards shall have its risks evaluated taking into account the likelihood and the severity of consequences of injury or damage (Figure 3). The managers shall use this evaluation for establishing their priorities' actions.

The construction company shall also establish a procedure to keep an ongoing identification of hazards and assessment of risk process that could cover new developments and new or modified activities, equipments and work sites, etc.

Activities, workplaces or equipments	Hazard	L	S	RD
Masonry	Repetitive movement	2	1	**2**
	High height (fall)	3	3	**9**
	Inadequate handling of materials	2	2	**4**
	Chemical exposition (Portland cement / dermatitis)	3	2	**6**
	Dust exposition (sweeping)	3	1	**3**
	...	**...**	**..**	**..**
L - Likelihood S – Severity RD - Risk Degree (L x S)				

Figure 3 – Example of hazards identification and risk assessment

2.5 Task 4 - Objective, Goals and Plans

The top management and the implementation work group shall establish and maintain documented occupational health and safety objectives and goals (Figure 4), at each relevant function and level within the organization. It should be quantified wherever practicable.

When establishing its objectives and goals the company shall consider: its legislation and other requirements, identified hazards and its risks, existing operational controls, the financial constraints, and technological options and business requirements.

Objectives	Goals	Measure method
To reduce the number of accidents	Reduce at least 50% till December 2002	Accidents Report (monthly)
To reduce the number of activities with high Risk Degree	Eliminate at least 3 activities with RD = 9 till December 2002	List of high risk activities
To apply new safety technologies	Apply at least 2 new technologies till December 2002	Number of implementation reports
To increase safety training	Training at least 2 hours each employee monthly (average)	Training hours report (monthly)

Figure 4 – Example of objectives and goals

The implementation work shall also establish an action plan for achieving each objective and goal. This shall include necessary activities, defined responsibilities and authorities and the time-scale (Figure 5).

Action Plan		**Number 035**
Objective: reduce the number of activities with high Risk Degree **Goal:** Eliminate at least 3 activities with RD = 9 till December 2002 **Measure method:** List of high risk activities		
Necessary activities	**Responsible**	**Time Limit**
Study the substitution of the process of manual digging for another process, with the support of a foundation specialist	Wilber	4 months
Study the elimination or substitution of the use of the XZ-R02 (hazardous substance)	William	6 months

Figure 5 – Example of an Action Plan

2.6 Task 5 - Operational Control

After the identification of hazard and risk assessment the implementation work group shall establish control measures for the elimination of the hazard or reduction of its risk. It shall determine and implement Safety Instructions (SI) for the activities, workplaces and equipments (Figure 6).

Such SI shall include:

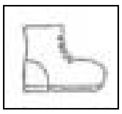
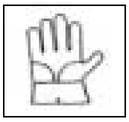
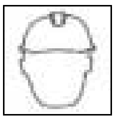
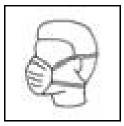
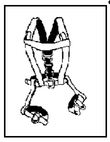
- Worker responsibilities and competences needed;
- Adoption of personal protective equipment (PPE);
- Adoption of collective protective equipment (CPE);
- Equipments needed;
- Safety guidance for employees, supplier or contractors;
- Procedures for the design of workplace;
- Legal requirements and others.

This shall be carried out considering the legislation, international bibliography, benchmarking studies and the practices of the organization. The employees shall be involved in the SI review, because they have greater knowledge of the process and will be directly affected by them.

Safety Instruction – Masonry **SI.01 Version 02**

1.Responsible: bricklayers team

2.Personal Protective Equipment (PPE)

Obligatory	**Obligatory**	**Obligatory**	**Cleaning**	**Work in Height**
				
Boot	**Gloves**	**Helmet**	**Protection Mask**	**Safety belt**

3. Safety Guidance

- As soon as possible remove the rubbish and dirties
- Use scaffold to work above 1,5 meters

4. Competencies needed;

- Team trained in use of safety belt and PPE conservation

Figure 6 – Example of a simplified safety instruction

For the implementation of the SI, the construction company shall provide every resource needed and establish a timely and systematic training process. It is extremely important for the success of the implementation and to obtain the expected results.

2.7 Task 6 - Documents, Data and Records Control

The construction company shall establish and maintain a procedure for creating and controlling all documents and data required to operate the management system. It shall indicate the person(s) authorizing approve the documents for adequacy before its use, and promptly remove obsolete documents. This procedure shall include a master list or indexes, list of controlled documentation and its location and a distribution control process.

The organization shall also establish and maintain a procedure for controlling its records (medical test reports, training records, inspection reports, reports of emergency response drills and others) in such a way that they are readily retrievable and protected against damage, deterioration or loss.

Identification	Current Version	Location
Safety Instruction SI.01 - Masonry	02	Wilber - 01 copy William – 01 copy

Figure 7 – Example of a documents control form

Identification	Storage local	Type of the archive and protection	Retention Time	Final Disposal
Daily Inspection Report (DIR)	Safety department	- Folder indexed by date - Free Access	Ten years	Picot

Figure 8 - Example of a record control form

2.8 Task 7 - Emergency plans

The implementation work group shall identify every potential emergency like fatal accidents, fire, leaking and others. After that, it shall create and document emergency plans and train every involved worker for preventing and mitigating the likely illness and injury that may be associated with these situations.

Such plans shall include:

- Provision, control and maintenance of organization's plant and equipment;
- Provision and control and maintenance of PPE;
- Shutdown systems;
- Fire detection and suppression equipment;
- Details of actions to be taken by personnel during an emergency, including those actions to be taken by external personnel who can be on the site, such as contractors or visitors;
- Responsibility, authority and duties of personnel with specific roles;
- Interface with external emergency services (i.e. hospital, fire department);
- Evacuation procedures, signalling, and others.

Practice drills should be carried out according to a pre-determined schedule for assuring its effectiveness. The construction company shall review its plans, in particular, after the occurrence of incidents or emergencies.

2.9 Task 8 - Performance measurement and monitoring

After the implementation of operational control, the implementation work group shall establish and maintain procedures to monitor and measure the occupational health and safety performance of the construction company on a regular basis.

Table 1 presents the essential topics that shall be measured and monitored and some examples of measuring and monitoring methods.

Table 1 – Monitoring measuring topics

Topics	Examples of measuring and monitoring methods
Extent to which the Objectives and Goals are met	- Measurable indicator; - Monitoring of the action plan results.
Applicable Legislation and Safety Instructions compliance	- Results of the legislation review; - Results of hazard identification and risk assessment; - Systematic workplace inspections using checklists; - Inspections of specific machinery and plant to check that Safety related parts are fitted and in good conditions; - Environmental sampling: measuring exposure to chemical, biological or physical agents (e.g. noise, volatile organic compounds); - Behaviour sampling: assessing worker's behaviour to identify unsafe work practices that might require correction; - Number of accidents, illnesses and incidents; - Costs of accidents happened and others.

If monitoring equipment is required for performance measurement and monitoring, the construction company shall establish and maintain a procedure for the calibration and maintenance of such equipment to assure correct results.

The mainly function of the performance measurement and monitoring process is to provide all necessary information to the managers so they can review the results and define actions plans to keep a continual improvement.

The construction company shall also establish and maintain a procedure for periodic occupational health and safety management system audits to be carried out, in order to determine whether the management system conforms to planned arrangements and OHSAS 18001 requirements, has been properly implemented and maintained and is effective in meeting the organization's policy and objectives.

This procedure shall include scope, frequency, methodologies and competencies, as well as the responsibility and requirements for conducting and reporting results.

2.10 Task 9 - Corrective and preventive actions

The implementation work group shall prepare a documented procedure to ensure that all accidents, incidents and nonconformities are investigated, and corrective or preventive actions are implemented.

All the managers shall be trained in this procedure, in such a way that all the occurrences are reported and studied to identify the root causes and to establish corrective or preventive actions (Figure 9). Checks should be made on the effectiveness of corrective or preventive actions taken.

Nonconformities: a worker has hurt his hand cutting a plastic pipe.
Causes: he uses a knife → he doesn't have the correct and safe tool (a pipe cutter tool) → he doesn't know how to use the pipe cutter
Corrective action: Train the worker about how to use the pipe cutter Eliminate every knife available in the work site

Figure 9 – An example of a corrective action

2.11 Task 10 - Management review

The top management shall review, at planned intervals, the organization's occupational health and safety management system, to ensure its continuing suitability, adequacy and effectiveness.

This review shall cover the results obtained through the performance measurement and monitoring process, results of internal or external audits, previous management reviews, reports from individual lines managers on the effectiveness of the system locally and reports of available resources. This review shall be documented and shall address the possible need for changes to policy, objectives and other elements of the management system, as well as to define corrective or preventive actions.

3 Results

The methodology presented was implemented in a building construction company in the State of São Paulo – Brazil. The company had already a quality management system based on ISO 9001 standard requirements, which facilitates the implementation process as some requirements of OHSAS 18001 and ISO 9001 are quite similar and compatible (i.e. documents control, audits and corrective actions).

The implementation process included a series of training and technical meetings in the office and construction sites, where each task was explained and adjusted for the existing practices.

The implementation process lasted 12 months and allowed the assessment and approval of the occupational health and safety management system by an international registration body in October 2002.

Despite the recent certification, some results were collected during the implementation process through interviews with managers and workers, as well as internal audits realised by one of the authors.

The results are presented in Table 2 and 3 subdivided by the methodology tasks.

Table 2 – Preliminary results

Task 1 – Safety and Health Policy	- Awareness of the workers in the construction sites and in the offices about the importance of a safe and health workplace and the company policy; - The top management presented a commitment to control the safety and health of the company.
Task 2 - Legislation and other requirements	- It was identified that the construction company did not have all the applicable legislation and some of them were obsolete; therefore they were acquired and updated; - It was identified some topics that were not complied because unfamiliarity of the company; - The first evaluation represents 85 % of legal documentation completely complied; after the implementation it was achieved 97 %; - It was identified some legislation that had been elaborated based in the industrial sector, having some obstacles for an application in construction companies; - Improvement of the relationship with the regulatory bodies, because some difficulties of interpretation and doubts were solved by contacting them.

Table 3 – Preliminary results

Task 3 – Hazard identification and risk assessment	- It was identified that the number of activities, areas and equipment for the construction companies is very high comparing to those of industrial companies; - The majority of the identified hazard has medium or low risk degree and there are few hazards with high risk degree; - It is clearly noted that after the implementation of the SI the average of risk has reduced;
Task 4 – Objective, Goals and Plans	- With the establishment of objectives and goals the managers were encouraged to involve their subordinates to achieve them; - The manager has a guide for his actions in the company and a useful tool for leadership;
Task 5 - Operational Control	- Much training was necessary to enable the Safety Instruction which have new practices for the organization; - The acquisition of new and better safety equipments was necessary; - The contribution of the employees in the elaboration of the SI was greater then expected; - The creation of partnerships with contractors was necessary for SI compliance, creating in some case especial requirement in the contract; - Documented instructions allowed all engineers of the construction company to carry out the safety and health training that was typically done only by the safety engineer; - The construction site had a visible improvement in terms of cleanness and organization of storage areas and living areas; - The furniture and equipments of the offices was changed in order to create a workplace with an ergonomic conception;
Task 6 - Documents, Data and Records Control	- Process already existed in the construction company and the mainly change was the including of all safety and health documents and records in the existing controls;
Task 7 - Emergency plans	- Personnel trained in first aid and fire brigades in all constructions work sites and in the officer; - Practice drill were carried out simulating a fire and accidents with victims in all constructions work sites and in the office; - The workers became awareness about their roles in an emergency situation and became more committed with the H&S policy;
Task 8 - Performance measurement and monitoring	- There are quantitative information that allow the manager take actions based on real data and not subjective like before; - The results of inspections reports pointed a significant reduction of nonconformities; - The results of the inspections reports had been used by the engineers of the construction sites in order to create a kind of a competition between work sites stimulating the commitment and involvement of workers;
Task 9 - Corrective and preventive actions	- This process already existed in the company and the mainly change was the including of all nonconformities related do safety and health, accidents and incidents. An initial difficulty for reporting the incidents was observed, which was surpassed with training;
Task 10 - Management review	- Process already existed in the construction company and the mainly change was the integration of the safety and health matters in the strategic level of the organization.

4 Conclusions

The predominant culture on the building construction sector privileges aspects like costs and delays, considering safety and health as an additional costs. However, the implementation of occupational health and safety management system establish a new posture, which considers the health and safety results as one of the components of the performance of the company.

The proposed methodology has proved its efficiency not only thanks to certification by an international registration body but also to the managerial and even cultural changes, affecting the organization and men.

Based in the initials results of the Brazilian construction company it is clear that the implementation of an occupational health and safety management system is extremely positive for construction companies, of any country. Every improvement obtained at each task of the methodology certainly results in a reduction of accidents, illnesses and incidents. Moreover, we must expect as results the following subsequent advantages, which could not still be demonstrated:

- Cost reduction (fines, lawsuits and productivity reduction);
- Preserve and development the image of the company for its customers, investors, suppliers, contractors, trade unions, regulatory bodies and society;
- Adopt a posture that exceeds the legal requirements compliance resulting in a competitive differential; and
- Increase of the satisfaction and quality of life of the workers resulting in a productivity improvement.

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The architectural executive project and the quality control on building site

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Abstract

Since 1990 a lot of companies have been trying to modernize their activities aiming to get the quality assurance that would evidence their commitment to quality philosophy and satisfaction of the expectations of external customers. In Brazil, the construction industry was the last to join the "run" towards certification, stimulated, after 1998, by the initiative of the Federal Government to modernize the sector through the implementation of PBQPh – Brazilian Program for Quality and Productivity in Habitational Programs. That program was designed to instruct the constructing companies to – step by step – comply with the requirements of ISO 9002:1994, helping them to translate the norms' requirements into tasks to be implemented by their work teams.

It is known that the design is responsible for a large number of pathologies in building construction. There are many tasks that contribute to such a distortion. The most important is the fact that the design is frequently developed without due consideration for the building construction system. The result of this absurd is design with less information than necessary.

This paper discusses the performance of de executive project in the offices and building sites through the opinions of the professionals who contracts, manager and use the project. Finally this work presents some guidelines for the development of executive project considering all the aspects related to quality management. This work is extracted of Master of Science Thesis developed on Architectural Post-Graduation Course (PROARQ/FAU/UFRJ).

Keywords

Quality control; builtability; exexutive architecture design.

1 Introduction

The selection of the subject of the present research was motivated by the interest on architecture projects, particularly executive architecture design. There are many reasons that justify the interest on this subject. One of the most relevant is the progressive distancing of the architect from the building site which results on projects that often cause problems to the execution, or, even before that, to the understanding of what is to be accomplished.

The purpose of the executive project, in agreement with SILVA (1998), it is expressed in the own denomination: it serves as instrument for the accomplishment of the building site work, presupposing the approval of the idea exposed in the draft must be considered a instructions system that will inform the way should be built the building.

BORGES (1998) coloca que nesta etapa é produzida toda a documentação final necessária para a completa descrição da proposta e realizada a compatibilização final entre todos os universos de competência envolvidos no processo.

SILVA (1998) it places although the primordial function of the executive project is then to communicate, implying the use of the language resources so that the communication is possible so that the adopted code it is efficient generating clarity and precision.

In order to develop this work, it was necessary, at first, to establish the intended focus, which is the constructors' point of view. Knowing that quality is defined as "the sum of the characteristics that are necessary to satisfy the established requirements", it became necessary to define clearly the **subject** of that action, that is, **who** was to name those requirements. In this work the executive architecture design was analyzed as the fundamental parameter for the establishment of a work process – the building site work – which will, at the end, result in a product: the building itself. In this regard, the subject who will establish the characteristics of such an executive architecture project is the constructor.

Once the focus of the work was determined, we went on to investigate the basic questions that are inherent to the theme, which are:

- whether the executive project takes into consideration construction technology
- whether its goal in the building process is in fact reached
- whether the form, language and content of that important step of the project helps the execution of the work.

2 Criteria adopted for the selection of the companies that were investigated

What is intended, as described in our Introduction, is to get to know the constructors' point of view about the architecture executive design, through the different departments of the company (commercial, supplies, budget, building, architecture, etc.).

The main goal of this approach was to accomplish an evaluation of the executive architecture design regarding the content – specifically related to the presented information, and not the spatial conception – graphic representation, data communication and other aspects that are fundamental to enable its use by working crews. Then we opted to carry out the research **only in construction companies** and not in project offices.

This study involved collecting data through questionnaires, interviews with professionals from different departments of the company and technical observations of in construction or just finished buildings.

The criteria used for the selection of the companies to be investigated were:

- they must have ISO 9002/94 OR ISO 9001/2000 certification; and
- they must produce multifamiliary residential buildings on Rio de Janeiro.

The selection was made through the catalogue of certificates of the CB-25 of ABNT (Brasilian Association of Technical Standards) (last updated in August/01) in the section "Construction", sub-sections "Construction of complete buildings and its parts: civil engineering" and "General building construction services and civil engineering".

Table 1 – Characterization of the companies

Items	Company A	Company B	Company C	Company D
Area of work	Civil construction, residential enterprises	Incorporation and construction of residential and commercial buildings	Construction of residential and commercial buildings	Incorporation and construction of residential and commercial buildings
Time in existence	20 years	48 years	39 years	15 years
Certification	ISO 9002/94	ISO 9002/94	ISO 9002/94	ISO 9002/94
Year of certification	2000	1999	1999	2001
Buidings being constructed	02	12	04	04
Existence of Project Department	Yes Project coordination	Yes Project management	No (1)	No (1)

Notes on Table 1:

1. In these two cases, the person who serves as the connection between the teams that were hired to develop the projects and the constructor is, in the first company, the Engineering manager and work coordinator; in the second one, the Work coordinator.

3 Description and analysis of the assembled data

3.1 Regarding the hiring of the projects and the flow

The criteria that were adopted by the researched companied for the hiring of projects are shown in Table 2 in importance ordering (from the most important one to the less one).

Table 2: Criteria used by the companies to contract projects

Criteria	Company A	Company B	Company C	Company D
Lower price	**1**			**1**
Punctuality in delivery	**3**			
Payment options	**4**			
Consolidated partnership	**5**	**1**	**1**	**2**
Quality of the project	**2**			

Among the fundamental aspects that were observed in that research, the following are to be highlighted:

- In the four companies, all the steps of the architecture project and other projects are left to third parties, except for the feasibility study, which is developed by internal personnel in **Company C**.
- **Company A** considers that "*the partnerships it adopts have quality and*

punctuality", thus prevailing the lowest price.

- In **Company B** the low price criteria is not used because the price of the services is not negotiated, for there is a project index, which is updated annually and used for all contracting.
- In **Company C** the architecture project is contracted with only one company for all its phases. It is a most peculiar case, for only ten years ago the constructor kept an internal architecture department in which all projects were developed. Following internal restructuring in the company, the department was extinct and its head opened his own office, thus creating a constant partnership with the constructor.
- **Company D** considers price to be the first criterion, followed by consolidated partnership for contracting, for it is used to asking quotations only from those of "*proven quality*". It also sees punctuality of delivery as being implied, even though it notices that "*no one is able to provide it*". It believes that "*impunctualities*" cannot be attributed solely to the projetists, because of changes that are required by the constructor and the fact that the time that is set to the activity is not always compatible with the quantity of work.

3.2 Regarding the execution of projects

Table 3 shows the kinds of projects that are usually contracted by the companies, Regarding the architecture project, some specialties other than the various phases of development were also included.

Table 3 – Relation of Contracted Projects

Tipology		**Company A**	**Company B**	**Company C**	**Company D**
Architecture	Study of feasibility	✓	✓	✓	✓
	Preliminary study	✓	✓	✓	✓
	Legal project	✓	✓	✓	✓
	Basic project	✓			
	Executive project	✓	✓	✓	✓
	Visual conception of the product [1]	✓	✓		✓
	Decoration project	✓	✓	✓	✓
	Landscape project	✓	✓	✓	✓
	Roads			✓	
Visual communication		✓	✓	✓	✓
Promotional	Perspective	✓	✓	✓	✓
	Scale model	occasionally	✓	✓	✓
	Electronic scale model	occasionally	✓	✓	
	Sales plant	✓	✓	✓	✓
	Virtual tour of the site				✓
	Internet site		✓	✓	✓

Note on Table 3:

1. The visual conception of the product is considered to be the definition of the image of the building, which comprises definitions of the form and façade specifications, appearance of some common use areas (entrance, floor halls, playgrounds, etc.) and in some cases the specifications to finishing materials of autonomous units.

The following points are to be highlighted:

- The person who is responsible for the visual conception in **Company B** is the same professional who formulates the project and who follows it on every phase (even though they are not hired for the development of the executive). In **Company C** the visual conception is done by internal staff, which provides directives to the author of the project.

- In **Company A** the executive project is developed by the same professional who is the author of the architecture project, but the manager wishes to change that procedure because some architects do not meet the requirements of the different phases entirely. Those professionals end up concerning themselves more with the legal aspects as opposed to the ones related to the production of the building. It is perceived that that company lacks something in the work of some professionals where the executive project is concerned.
- Still regarding **Company A,** there are formalized technical project premises that are presented to the projectists together with a list of the preliminary specifications in the initial coordination meetings. There are standard details notebooks that are differentiated according to the building standard. In **Company B** the executive project is normally developed by the same professional who is the author of the architecture project, but when the legal project is already included in the negotiation of the enterprise – in this case done by a professional other than the already consolidated partners – the constructor hires one of the latter. In this case, the author of the project is hired to follow the development of the service.
- In **Company C**, as reported in the previous item, the architecture project is always developed in the same company in all its phases.
- The executive project in **Company D** is developed by the same professional who is the author of the architecture project. This is due to possible legal problems because of modifications that cannot be approved that were done in the executive phase. They believe that the problem can be avoided if the project remains under the responsibility of a single crew.

Table 4 refers to the complementary and production projects that are usually contracted by the researched companies. The following were considered as basic structures: electrical, special (telephone, antennae, cable TV, lightning-rods, logic), gas, drain and hydraulics. It should be pointed out that in the four researched companies projects are developed with the use of computing, but there are a few exceptions in

Table 4 – Types of complementary and production projects that are normally contracted by the researched companies

Typology		**Company A**	**Company B**	**Company C**	**Company D**
Topographic survey		✓	✓	✓	✓
Structural		✓	✓	✓	✓
Installations	Basic [(2)]	✓	✓	✓	✓
	Fire prevention	✓	✓	✓	✓
	Air conditioning	✓	✓	✓	✓
	Mechanical exhaustion	✓	✓	✓	✓
	Internet	✓	✓		✓
	Building automation		✓		
	Luminotechnics		✓		
	Acoustics			✓	
Production / consultancy	Ground		✓		
	Forms	✓	✓	✓	✓
	Aluminum plaques	✓	✓	✓	✓
	Seal	✓	✓		✓
	Façade covering	✓	✓		
	Fixation of stones on the façade	✓	✓	with restrictions	✓
	Concrete floor	✓			

3.3 Regarding project control and management

Table 5: Project control and management in the researched companies

Items	Company A	Company B	Company C	Company D
Project receiving		✓ D	✓ D	✓ D
Project distribution	✓ D	✓ D	✓ D	✓ D
Revisions control (updated versions)	✓ D	✓ D	✓ D	✓ D
Notes of revisions on the drawings		✓ ND	✓ D	✓ ND
Use of extranet				
Project as built	✓ I	✓ I	✓ I	✓ I
Auditing / verification of projects	✓ I	✓ A-S-I		✓ S-I

D – documented ND – non-documented A – architecture S – structure I - installations

The following aspects are highlighted:

COMPANY A

- Projects are received via e-mail or diskette. As only one person (the project manager) is responsible for receiving and only they have access to CAD program, this form is considered to be reliable.
- Regarding the modifications in the drawings, the notes on the stamp, at the judgment of the projectists, are considered to be satisfactory by the company
- The company does not use extranet for project management, but it believes that it will be able to implement the system with more buildings to make.
- Regarding the auditing of projects, the installation ones is verified by only one professional who is considered by the management to be very able. In the recent past, the projectists themselves verified structural projects.

COMPANY B

- Project control and distributing are done as follows: they are received via e-mail, filed, printed, reviewed and distributed. The tractability of the process is guaranteed because all procedures are documented.
- Project control is complemented by a general evaluation by the projectists in which aspects such as price, quality and lack of compliance with the budget are verified. From this evaluation prizes, fines and terminations of partnerships are employed according to a grading table in which weights and percentages for every analyzed item are discriminated. A part of the amount related to the service remains held back until the process is finalized. The manager claims that the adoption of those mechanisms brought about a significative improvement to the whole process, because of the involvement of all participants.
- The use of extranet as a project management tool was tested in a single enterprise but did not work as it should, for, among other things, the projectists could not adapt to it. The company intends to continue the implantation of this kind of system soon, for it believes that it will bring positive results to the entire process.
- Both installation projects auditing and structure auditing are done by professionals who are not part of the staff of projectists hired by the company. The internal projects department does the verification of the architecture project.

COMPANY C

- The archive clerk who is also responsible for their distribution and control receives projects via e-mail. From the receiving of projects by the construction, it takes over their distribution and control. The procedure for revision notes on the drawings demands precise discrimination of all the modified elements. The recording and documentation of all procedure guarantees the traceability of the process.
- The “as built” installation project is done by a hired company that follows the execution of the services. The manager finds it difficult to control the information generated by them.
- Although the company does not contract project verification for residential buildings, it believes that that is a healthy practice, but it is observed that not all of the hired professionals think so.

COMPANY D

- In this company, as soon as the projects are received there is a preliminary verification of conformity with what was contracted. The document is then printed and delivered to the one who is responsible for analyzing it. If there are any complaints, it is handed back to the contracted party. If the project is fully approved, it receives a stamp that indicates that it is approved for use.
- While the enterprise is being studied, there are no formal distribution controls. It is only when they are in the execution phase that they are sent to the building site by e-mail with automatic confirmation that it has been received. It should be pointed out that this mechanism does not always work as it is supposed to. Phone confirmation is often necessary.
- Regarding the “as built” project, the manager comments it is not “*as he would like it to be*”, as it prepared by the technician and not by the projectist and not always with the necessary precision.
- The verification of the architecture project is done by the manager first and then by the building engineer. When digital files are received there are often problems caused by the lack of reference in their names as to which revision they refer to. In this case the manager has to open the file to see which revision it is. This process leads to lost time not considering the loss of files by juxtaposition. Another frequent occurrence is the lack of revision by the projectists in the drawings before they are delivered. That leads to gross mistakes in the very name and address of the building.

4 Performance of the executive project

The goal of this item of the research was to identify the opinions of the professionals who contract, manage and use the executive project on its performance in its use by working crews. The word performance is used in civil construction to refer to the behavior of a product when in use. The concept is used to make it clear that the product is supposed to present certain characteristics that enable it to fulfill the objectives it was designed/produced for, when it is submitted to certain conditions of use (CIB, 1982 apud NGI, 2001).

We present below summaries of the interviews that were done in the offices and building sites of the respective constructors (with engineers and e crew chiefs). The observations made by managers are based on data that refer to the development of all the projects they followed in the company. In the field research, the data that was collected and that which was noted by the interviewees referred only to the visited site.

For better understanding of the observations, at the top of each table there is information on the kind of enterprise that was object of the research. The items that are highlighted in gray refer to the main aspects named by the managers and the others, by the field personnel.

Table 6 – Company A

Characterization of the researched enterprise	- Enterprise composed of several residential buildings with an access area that is common to all. - The projects were developed well before the beginning of construction, but without the participation of the engineer in the coordination meetings. - Each building is in a different stage; some have already been finished.
• The manager observes that not all hired projectists are able to hand in executive projects that meet the demands of the building. In a broad way, he detects in the projects a lack of detailing. Regarding the compliance with technical rules, the constructor considers that the projectists are not always up-to-date. • In the site problems were identified: → as to the definitions/information on the project, some have caused problems in the execution; → as to the readability of the drawings. → as to the compatibilization (it should be noted that the manager believes that few projectists do efficient compatibilization).	

Table 7 – Company B

Characterization of the researched enterprise	- Enterprise composed of four residential buildings with access and leisure areas that are common to all. The projects were developed well before the beginning of construction, with the participation of the engineer in the coordination meetings. - Each building is in a different stage; some have already been finished. - This enterprise has the possibility of personalizing the apartment, thus allowing the buyer to choose the type of plant and the finishing materials from the alternatives presented by the constructor.
In a broad way, the projectists meet all requirements, demands and expectations of the constructor. The large number of existing standards and the detailed definition of the aim make the work easier. • Regarding the compliance with technical rules, the constructor considers that the projectists are always up-to-date. • Because of the characteristics of the enterprise, the constructor designated an architect to the building site to verify/evaluate the projects, which, according to the engineer, has resulted in a considerable improvement for them and fewer revisions.	

Table 8 – Company C

Characterization of the researched enterprise	- Multifamily 16-floor building. - The executive project is in the pre-execution stage, and the engineer does not participate in the coordination meetings. - Phase of the building: beginning of foundations.
• The manager's strongest criticism concerns the lack of "*physical vision*" of the professional who did the EP, having yet to associate to the project notions related to the professional practice (execution of the work) and lack of concern about the difficulties of the execution (*builtability*). → The engineer states that the excessive number of project revisions during the execution of the services and the lack of compatibilization between the projects are the most frequent EP-related problems. In some cases the modifications get to the building site after the end of the execution, which leads to waste of material and manpower. → Another item that was pointed out as a problematic one is the thickness of the coating projected for the floor (3 to 4 cm), which normally needs to be increased at the building site due to irregularities in the paving-stone (often because of the little time available for the execution), crossing of inside pipes, among others. • Regarding the compliance with technical rules the constructor considers that the projectists keep up-to-date. The manager says the rules are outdated themselves.	

• Suggestions for the improvement of the project: → The engineer suggests that after the pre-execution project is received a team of engineers from the constructor analyze it. He believes that, with the sum of knowledge and experience of the members of the team, various possible problems can be solved in time. → Indicate the area and the perimeter of all compartments, aiming to help in the quantification of materials.

Table 9 – Company D

Characterization of the researched enterprise	- Multifamily 18-floor building. - The enterprise was acquired from another constructor which already had a contract with an architecture office for the development of the project - In this case, no project procedure normally required and adopted by the constructor was considered for its elaboration. - Phase of the building: finishing.
• The following critical aspects were identified: lack of detailing, insufficient quotas, lack of objectivity/coordination in the placement of information, lack of precise specifications, lack of revisions in the drawings from the projectists before they are delivered. In a broad way the project lacks information, which makes it necessary for the engineer to consult with the projectist constantly. • Regarding the compliance with technical rules the constructor considers that the projectists follow the existing rules. obs: The compliance with this item is foreseen in the service contract. • Problems related to the readability of the drawings were also identified. • The following also caused problems for the execution: → some project definitions/information → compatibilization failure; → project delivery punctuality failure	

5 Final Considerations

The first aspect that attracted attention in the comparison of the collected data was that, out of the four companies that agreed to participate in the research, only one effectively plans its actions, integrating the project to the work. It was also observed that such concern with planning has brought about better results in the performance in constructions that are in progress. The planning model adopted by that company has as a basic assumption guaranteeing that the professionals who work in the production of the building participate actively of the different phases of the elaboration of the executive architecture project. That measure has as its main goal to put an end to the traditional “barriers between departments”, integrating project and building.

In a general way the executive project doesn't assist the expectations of the contracting parties fully for several such reasons as: lack of detailing, unfamiliarity to the professional practices, lack of objectivity and ordering of the information and legibility of the drawings.

The lifted up data show that the companies building the totally of the projects are left to third parties that, in a certain way, it distances the planners of the building sites once the same ones are not contracted for visits and periodic verifications of the execution.

It is worth to stand out that the planner's work is facilitated when an expressive number of standardizations of the constructive elements exists on the part of the contracting parties as well as a very defined and detailed epurpose. It is the case of the Empresa B where we can verify an almost total satisfaction with the acting of the project.

However, the main problem as all the interviewed constructors identified it refers to the compatibilization of projects. The fact that most times there is no proper management and control leads to the development of incomplete projects, without the minimal details for the proper execution of the work. Besides that, the lack of dialogue among projectists eventually results in incompatibility among projects. That incompatibility is often only detected at the moment of execution and the construction crew has to solve the problem.

It is a matter of consensus among the interviewees that the form of contracting projects often harms their own proper development. Project offices are given work development deadlines that, on most occasions, make it impossible to develop an executive project with all the information it requires. Therefore, it can be concluded that one of the measures to be adopted for adequate project development/coordination is not only in the hands of projectists. It is necessary that constructors, as happens to other service providers who work on buildings, start to establish a relation of commitment towards projectists and that that new relation expresses itself in forms of contracting that effectively consider the gravity of the work to be developed.

It is understood that the subject herein covered could not be studied in its entirety, as the preoccupation with project development by constructors is still recent. The project PSQ – Sectorial Quality Plan – integral part of the PBQPh (Brazilian Quality and Productivity in Housing Program) – starts to be discussed in all states and much has yet to be studied to guarantee a proper relationship between who develop the project and who executes the construction.

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Guidelines for the formulation of a new quality management system model for design firms

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Abstract

The globalisation of markets, the change in consumer behaviour, the new equation for the formulation of prices and the increasingly tougher competitiveness have stimulated the Brazilian construction design firms to increasingly adopt Quality Management Systems as an alternative to improve their internal systems and for offering products with higher quality. However, the model of Quality Management System which is being adopted by these firms has not generated the expected benefits.

There is an evident difficulty in the adaptation of these systems to the characteristics of the design firms, which in general are small businesses and have a low turnover when compared to that of contractors. The implementation and maintenance of these systems has become too expensive for them and has not allowed them to join the Project Quality Plan in a harmonious way, due to the difficulty in overlaying the Quality Management Systems of the various project players.

This paper intends to formulate brief guidelines for a new Quality Management System Model which takes into consideration the real necessities of design firms; their organizational structure; the management of their interface with other players; and which would make viable their introduction within the context of the Project Quality Plan, so as to generate profits not only for them, but for all of the participants in the production chain.

It is expected that this new model will help to reach the strategic goals of the projects; which will allow better control of costs, delivery time and quality of the final product; increase the integration between design and production; improve the manner in which the needs and expectations of the clients and the project players are satisfied; and increase competitiveness of the project firms and the final product quality.

Keywords

Design firms management; design process management; quality design

1 Introduction

Organizations all over the world are facing a new reality. Today new word is "change". And in civil construction it would not be different, with ever more competitive scenarios – where the price is set by the market – organizations are under pressure to restructure and be equipped with new tools and techniques to survive under this new order.

It is well known that design activities have a great influence on the performance of a building during its use, and more than this, it determines, to a great extent, the possibility of real financial gains during its construction by reducing wastage, decreasing the building pathology indexes, improving the corporate image of the company, leading to an increase in the number of sales, etc.

Today, despite the evident importance of the design process in civil construction, there are still no deep and thorough studies on the incompatibilities and difficulties of adapting current models of Quality Management Systems to design firms. The fact is that there is a serious problem in adapting these tools and techniques to the organizational realities of design firms which have very special characteristics and will be better analysed further on.

Innumerable studies on techniques and methods for improving the design process have been conducted and interesting results obtained. We believe that these results could have a wider practical application and generate greater benefits if the managerial style of the design firms, that wish to introduce these new techniques and methods, are taken into account.

The success of any proposed improvement to the design process is closely linked to the general performance of the design firm in question. Therefore, elements and functions connected to the management, such as the organizational culture, entrepreneurship, organizational structure, decision taking, leadership, information system, etc., if well developed and implemented, significantly influence the development of design activities, providing the ideal conditions for the development and implementation of improvement programs and methodologies focused on the design process itself.

Due to the importance of design in the general context of civil construction and of the difficulty in adapting current models of Quality Management Systems to the reality of design firms, this paper aims to present initial guidelines for the formulation of a management model for design firms, which will consider their organizational characteristics, carried out from a theoretical consideration based on bibliographical exploratory research. This study is still ongoing as a research for a doctorate in the Civil Construction Engineering Program of Escola Politécnica, University of São Paulo, Brazil.

2 The role of design in the construction process

In strategic terms, design has to achieve the organizational goals of the various components that make up the project: financial return, improvement of the client image, increased share, etc. While in operational terms design should set out the physical characteristics of the product (scheme design and definite design), its execution method (design for production and site design), facilitate the introduction of technological innovations, reduce the existence of building pathologies, guarantee quality characteristics, rationality and constructability of the product, allowing for its better use, reduction in execution lead time of the works and a reduction in total costs.

Greater attention to the design activity has lead to the awareness of the importance of taking decisions for the solutions involving the execution and technology of the product while still in the conception phase. This procedure allows for the reduction in interference and subjective decisions in the execution phase, giving greater coherence to the aims and goals initially planned, greater production speed, easier compliance with the planning and rationalization of resources management, etc.

A good performance of the design process depends on diverse factors of different kinds and amplitudes: the existence of a complete briefing of clients' needs, an increase in effort in the initial conception stages of the project, simultaneous collaboration among the various specialties of building design, development of precise construction details aimed at the execution phase, integration between the conception phase and the production process and, mainly, the existence of a management infrastructure at the design firms that allows for the development and realization of the previous items.

Two important dimensions can be attributed to the design: both as a product and as a service. In the product dimension, the design is represented in the form of documents containing technical and geometrical details, which can be taken as the final product and, still as a process, seeking solutions to the construction problems of the building product, in order to meet the necessary needs and requirements. While in the service dimension, the design must be seen as an integral activity of the production process, responsible for the development, organization, registration and transmission of physical and technological characteristics specified for a construction which are to be considered in the execution phase.

The efficient application of these new definitions results in a significant transformation in the structure of the design activity, meaning a structural change in the methodology of its development and consequently an adjustment to the management system of the design firms.

The design process can assume the fundamental responsibility for adding efficiency and quality to the product if it is incorporated in an advanced and adequate manner to the planning of the production process and used to induce rationalization and reduction of costs.

So design must have information of technological matters (construction details, location of equipment, quality control, etc.) or managerial nature, serving as support to the planning and scheduling of the works. The design firm has to offer minimum conditions for the designers to be able to give the design the characteristics that meet all the technical and managerial demands concerning the site works.

3 Recent advances in the design process

An important tool for the improvement of the performance of the design process is the **concurrent engineering** philosophy. This philosophy seeks to integrate, in the conception phase of the project, all of the intervening factors, so as to generate, in this initial phase, decisions related to the design based on the experience of all the players acting in the project, who will work as a team, considering quality, cost, time and clients' requirements, with the main goal of reducing time between the development of new products and their launching, establishing a price and quality that allow the conquest of a larger market share. Requirements for good simultaneous engineering performance depend on the existence of an organizational environment with minimum management conditions.

The construction technology is “built-in” the execution processes by design. However, the reality of building sector practices shows that the design itself does not always incorporate the construction technology effectively used on the building site. In most cases, the design limits itself to the definition of the product without incorporating its construction methods and processes, the material and the equipment.

Recently in the building sector, a considerable growth was observed in the use of **design for production**. This tool defines the construction techniques to be employed in the construction process and the designed construction details. The objective of this kind of design is to minimize the uncertainties in production, by the anticipation of execution activities, being applied to various sub-systems of the building, allowing a detailed local view in terms of pre-studied solutions and a general view of the entire sequence of execution.

The basic function of design for production is the transmission of all the conditions that involve the construction technology chosen, in order to aid the execution phase of the project as complete as possible, thus avoiding improvisation, stoppages, re-work and the implementation of a non-planned solution during the execution.

Design for production also aims to reduce costs, which is one of the major concerns of entrepreneurs; it also seeks to optimise the production process allowing better productivity and quality of services.

Another technique that has been the object of recent studies in Brazil is **design co-ordination**. It is a multi-disciplinary activity that should be practiced by experienced professionals, in an impartial and unbiased fashion, representing foremostly the following basic objectives: to orient the design team and guarantee compliance with the clients’ needs; to guarantee coherent and complete designs, that is, without conflict among the specialties and without points being left undefined; to coordinate the design development, distributing tasks and establishing deadlines, as well as disciplining the information flow between the players involved in the project, transmitting and consulting data, organizing integration meetings and controlling the quality of the “design service”; and to decide between alternatives for the solution to technical problems, especially in the interface among specialties.

Fruchter et al. (1993) emphasized that **computer tools** can provide significant support to the communication of design concepts and problems among specialties. Besides, people involved in the design and execution of a building normally work for different companies and the group of participating firms varies from one design to another. The peculiarities of each design hinders the establishment of work routines. It is necessary to coordinate the contributions of each participant because of the existence of a vast amount of information.

Galle (1995) and Teichholz and Fischer (1994) highlight that changes in design made by one participant introduce conflict, as they are not automatically reflected in the drawings, reports and databases of the other participants. Without procedures for development that can register and review drawings, errors are expected. The additional time required for these procedures adds costs to the development process besides time itself. Consequently, according to the authors, using a common model, which aims at integrating all the participants, could limit the impact of these problems and increase productivity, highlighting the need to seek concrete alternatives to the controlled channelling of information between designer-designer and designer-site teams.

The use of a **database on construction technology** has also been shown to be an interesting tool in the design process. It must be permanently updated and must contain information, in a graphic or written form, relative to the technological characteristics and the construction solutions used, being an integral part of the general information system; it must be also available for use in design activities for all professionals in the design firm.

4 Problems in the design process

There is frequently a separation between design and construction activities, where design is generally understood as a simple isolated tool, as its deadline and cost are generally compressed, having an almost merely legal content, on the verge of becoming simply indicative and postponing a large part of the decisions for the production phase.

In building construction, the design of different specialties are generally developed in parallel by the various designers (architecture, structures and installations) being united only at the execution of services. This procedure generates a series of incompatibilities that compromise the quality of the product and cause enormous losses of materials and productivity.

Buildings are becoming ever more complex due to the demands of the clients, new materials and technologies. One part of the complexity of modern designs is related to the product and the other part to its production process. The technical and economic conditions that limit the development of a construction project are specific to each new design and the previous experience of designers does not often cover particular aspects that the client sees as imperative (Tatum, 1989).

The decisions as to the form, functionality and construction methods are taken at the conception and design phases of the project and at these phases the promoters and designers usually work with little information; this factor increases the variability and uncertainty inherent in the process. The great variety of performance requirements and components required by the construction designs also contribute to the increase in complexity as the greater the complexity of the product, the greater the complexity of the process. Because of these factors, it could be said that design has a problem of poor definition from its beginning.

In the design process, in general, the information is spread without any structure or classification, leading to many problems between the parties involved (Aouad et al., 1994). The constant change of suppliers, the dynamic relationship between the agents and their different interests (their personal aims and their distinct needs) are factors that make it difficult for the process to be flexible and also tend to increase the difficulty of exchanging information.

Also to be considered are the different professional formations, that influence this process, as generators of problems in design activity. Due to these differences, each professional or group of professionals develop different perceptions in relation to nomenclature and to the content of design activities. Besides this, these professionals are generally found physically distant and, usually, there is no clear relationship between the functions and the responsibilities of each actor involved.

According to Glavan and Tucker (1997), the design problems can be listed from the following macro-groups: plan drawing (interference, discrepancies, omissions and errors); programming (lack of necessary information, the need for further information on some detail from the designer and the need for drawings to complete the services); design conception (design errors and design changes) and specifications (need to clarify information, incorrect specifications and changes in specification during the process).

The design deficiencies can bring serious consequences for the construction process, to the extent of making the project unfeasible. According to Tilley and Barton (1997), a low quality design can generate the following effects: reduction in the efficiency of the construction process, increased risk to the construction contract, increased costs for both the contractor and the end client and increased lack of quality in the project.

The following factors can still be pointed out as difficulties in the implementation of changes connected to design activity: lack of specification for product characteristics, establishment of very short deadlines, lack of technical requirements to orient the architect, development of the design in a compartmentalized manner, difficult relationship between the contractor and the design firm, incoherent payments to designers, thorough review of the detailed design only in its almost final form, areas of supply, planning and costs don't give adequate support for the decisions to be taken at the design stage and the absence of feedback and the registration of solutions given for construction problems during the execution.

Table 1 shows the main difficulties faced by the design sector in relation to quality, according to the Brazilian Program for Sector Quality – PSQ.

Table 1 – Difficulties in the design sector (Adapted from PSQ, 1997)

Systemic difficulties	- Engineering and architecture courses do not match market requirements; - Illegal exercise of the profession, deficient inspection from the regional counsels of the professions linked to construction; - Lack of incentives for research; - Low level of requirement from public and private clients regarding design quality; - Sharp fluctuation in market demand.
Structural difficulties	- Fragmented sector, with large number of active professionals and fragmentation of the design development process; - Absence of methodologies for tracking the demand for design, which would allow adequate planning for the mobilization of professionals at all levels of the sector; - Lack of integration between the design and production process and the civil construction production chain.
Sector difficulties	- Lack of adequate methodologies for quality management in the design development process; - Lack of investment capacity for the improvement of the production process: qualification of human resources, computerization and development of own methodologies; - Difficulties in keeping teams; - Low level of integration with other professionals involved due to clients' hiring methods; - Difficulties in following the evolution of construction technology; lack of integration with technological leaders; - Lack of standardization of procedures among clients; - Lack of technical norms based on performance requirements of the building and its parts.

The development of a new model for Quality Management System for design firms would certainly contribute to the improvement of this scenario by reducing several of the problems mentioned above , bringing substantial minimization of waste and building pathologies, allowing compliance with deadlines and the manufacture of products (buildings) with quality compatible with clients' expectations, generating more competitiveness for the building sector organizations and making a contribution towards the achievement of their strategic objectives.

It is important to stress that this work is only the beginning of considerations regarding the formulation of this new model for quality management of design firms, focusing mainly on the improvement of the management structure and, therefore, a synthesis of the scientific uneasiness which led to a doctorate research on the theme.

5 Guidelines for management of design firms

We believe that it is not possible to achieve all the potential benefits from the proposed changes to design process if we give less importance to the management infrastructure of the companies which are responsible for its production. The changes in design methodology may generate significant productivity gains, but this requires a new organizational structure and the modernization of management tools.

Like all other organizations, design firms behave in a systemic manner, interacting with the surrounding project environment (see Figure 1). They cannot have their sub-systems analysed separately because they are interactive and inter-dependent. The work of these subsystems as a whole is the generator of the necessary synergy to achieve organizational objectives. Therefore, it is as important to study and to analyse the design process, as it is to study and to analyse the other subsystems of a design firm.

The design process represents the "production subsystem" in a design firm, therefore, it is very important to study the other subsystems of the company (human resources, materials, finance, marketing, information system, etc.) besides other managerial elements such as organizational structure, leadership and entrepreneurship, organizational culture, etc., in order to unite the minimum conditions for the design to be efficiently and effectively developed and that its improvements can be successfully implemented.

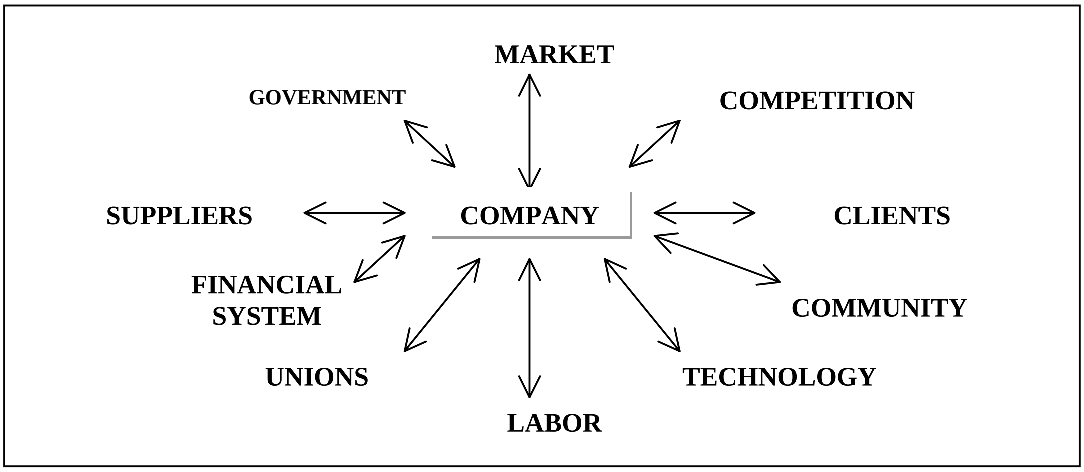

Figure 1 – A company system environment

The organizational structure of a company is an orderly set of responsibilities, authorities and decision processes, as well as defining how the tasks within the organization are to be allocated, who reports to whom and which formal coordination mechanisms and interaction standards are to be followed.

From this point of view, it can be concluded that the definition of the organizational chart depends on the company's perception of the environment where it is located and which should be in line with its strategies. The changes planned for the organizational structure can be considered one of the most efficient means of performance improvement within a company system. When an adequate organizational structure is established, it allows: better identification of tasks; better organization of functions and responsibilities; availability of adequate information, providing actual feedback to employees; the adoption of performance measures compatible with the company's objectives; and motivational conditions for the employees, contributing, to a large extent, to the good operation of the existing quality system.

Another aspect to which due importance is not yet given during the development and implementation of a Quality System, mainly in design firms, is the management of subcontracted services. Despite the respective explicit requirements of the existing models, which can be certified or non-certified, there is still a lot to be done in the design sector as, in general, subcontracting has been wrongly considered as a means of financial gain without the actual onus of the transfer of responsibility for the service.

Generally, product specification is not clearly defined by the contracting party, and on many occasions it is subject to the subcontractors conditions. The assignment of technical and financial responsibilities, in general, is not understood or agreed upon by the parties in a clear and well defined manner. On many occasions, a service is rendered without the subcontractor assuming its technical and legal responsibilities, or providing maintenance support and guarantee for defects of a badly rendered service. Nevertheless, this is a situation that must be avoided by the parties entering into agreement and which must be seriously considered in the Quality Management Systems.

Most firms are of micro and small sizes, where owners act both as management and in the technical production of services. This peculiarity gives these organizations high dependency on the level of entrepreneurship and leadership of its owners, which is also a characteristic that is not being taken into consideration during the implementation and development of Quality Management Systems.

Entrepreneurs make all the difference between the success or failure of a company. They promote integration which combines the talents of the technicians with the marketing and management elements, establishing new products, processes and services. Without them innovation remains in a rhythm which is inadequate for an highly competitive environment.

The entrepreneur cannot be separated from the company, both are part of the same team and should be perceived as one. The owner and the company employees influence the company entrepreneur "personality" and, therefore, can substantially contribute to the success of the Quality Management System.

In the design activity, contrary to the traditional manufacturing sector, there is no possibility to clearly separate the production process from the rendering of services – they can be confused. Thus, in the rendering of services environment, the Quality Management is basically centred on the interaction with the final user and with the contracting party. It is in this process that the quality appears.

It is difficult to maintain within a company, services of the same standard of quality, because in the same team there could be differences in the quality of the processes due to the different capabilities of each individual and also differences in the interaction with clients.

The greatest difficulty in the search for excellence is the constant modification of the client's behaviour. Their requirements are constantly changing and the improvement effort, in the face of changing targets, makes achieving excellence even more difficult. A policy for system feedback must be created using the final clients' complaints and assessment by the contracting parties, so as to further improve the performance standard of the service/product being offered.

Generally speaking, the generic guidelines proposed in this paper, arising from the considerations of the inter-dependency of the design with the management of the companies that produce it, are the following:

- Adjustment of the Quality System to the size and resources of the company;
- Systemic visualization of the design process, considering its interactions with the surrounding project environment and taking into account the other subsystems that make up the design firms;
- Matching of the design firm organizational structure to the design process characteristics in civil construction;
- Development and implementation of a methodology for the management of third-party services which will guarantee the quality and distribution of responsibilities;
- Consideration of the level of entrepreneurship and the leadership style existing in the design firms, which in general have a high level of dependency on their owners;
- Consideration of the design firms as producers as well as service rendering companies; recognizing that their professionals have distinct capabilities and characteristics and that, therefore, need efficient training tools and orientation for their work routines;
- Consider the clear identification of the clients' requirements as a basic element for the good performance of the design process;
- To improve the company information system, also including the use of communication between designer-designer and designer-client as well as the management of documents as indicators of the capacity to render design services;
- Institution of systematic feedback so as to make the continued improvement of the design activity and the quality management system as a whole viable.

6 Conclusion

Our conclusion is that it is possible to improve the performance of construction projects with relatively reduced investments – if compared to the investments that would be necessary in the construction phase – through management and improvement of quality within the design firms. Therefore, a more systemic, managerial approach, which takes into account the peculiarities of design firms, is essential to guarantee significant progress in civil construction projects.

This paper was not meant to be a treatise on design firms management or even on the design process in civil construction. Its main aim was to present generic and introductory guidelines for matching the management system of the design firms to the needs of its own production process.

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Site management approach to reduce material waste

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Abstract

Material waste has been an important issue to be addressed in order to reduce environmental impacts of the building construction activities. The extra mass of materials expended (Souza *et al.*, 1999 [8]) can be as large as 25% of the amount prescribed by the design. In this context, Brazilian construction companies have been trying to implement actions aiming to improve materials management.

This paper describes a case study where the authors coordinated an experience, in a building construction site in São Paulo, where a new management approach was adopted. Based on an extensive database, collected from more than one hundred construction sites, weekly meetings were held, gathering together site and subcontractor managers, in order to evaluate the previous week's job performance, to define actions to be implemented to improve the job process, and to define goals to be achieved in the next week. Due to the objective tools used, the main contractor and the subcontractor were induced to act as partners, and the detected material waste index was smaller than the minimum value of the available database.

This paper describes this experience (the method adopted, information and decisions related to every week meeting) concerning the target of reducing concrete blocks waste.

Keywords

Materials waste; construction management

1 Material waste in the building construction process

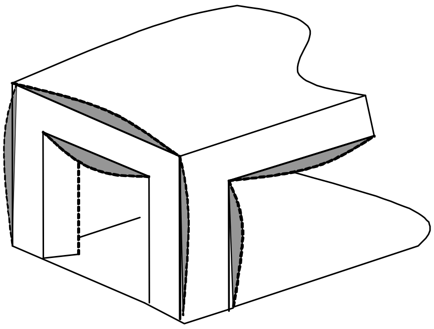
Several researchers indicate that material waste in the building construction industry is very significant. Enshassi [3] obtained a 5.2% waste value for common bricks, in 86 sites studied in the Gaza region; Skoyles [6] verified the value of 7% for concrete blocks waste in one building site, Pinto [4] presented a value of 13% for block waste and Soibelman [7] obtained median values of 52%. Therefore, this is a very important subject, both in terms of the revenue the contractor can get from the site activities or in terms of the amount of natural resources that is consumed in the building construction process.

In order to discuss block waste, this paper firstly defines material waste and then it describes the level of brick/block waste the authors found for laying blocks activity job.

1.1 Material waste: concept

A worker wastes material every time he/she uses an amount of material above the essentially necessary amount to produce a job. For example, if $110m^3$ of concrete is demanded to produce a $100m^3$ concrete structure, $10m^3$ of concrete were wasted (Figure 1).

In terms of essence, the waste could be apparent (leftovers) or incorporated in the construction (over-embodied material).



a) structure's over dimensions

b) debris at the unloading place

Figure 1 – Concrete waste and its nature: a) incorporated waste – structures over dimensions; b) apparent waste – concrete's debris in the truck.

This paper measures material waste as follows:

$$MLP = \left[\frac{RMQ - TNM}{TNM} \right] x100 \qquad (1)$$

where:

MLP	= material loss in percentage
RMQ	= real material quantity used
TNM	= theoretically necessary material

In the case of brick/block waste, the embodied parcel (Figure 2.a) is seldom detected; the waste normally appears in the nature of debris (Figure 2.b).

a)

b)

Figure 2 – Brick/block waste: a) embodied waste; b) debris.

1.2 Figures about bricks/blocks waste

The authors coordinated a very extensive research where almost one hundred construction sites were evaluated in terms of material waste measurement. Table 1 indicates the results for brick and block waste. The position measure (median), dispersion measures (minimum and maximum values) and the sample size (n) are presented.

Table 1 – Brick and block waste in the Brazilian building construction (Agopyan, 1998 [1])

Material	**Material Loss in Percentage (MLP)**			**n**
	Medians	**Minimum values**	**Maximum values**	
Bricks/blocks	13	**3**	48	37

The waste figures analysis indicated the main factors causing the waste (Figure 3) were:

- inadequate transportation of blocks;
- low quality materials;
- bad storage conditions;
- inappropriate equipment used to cut the blocks.

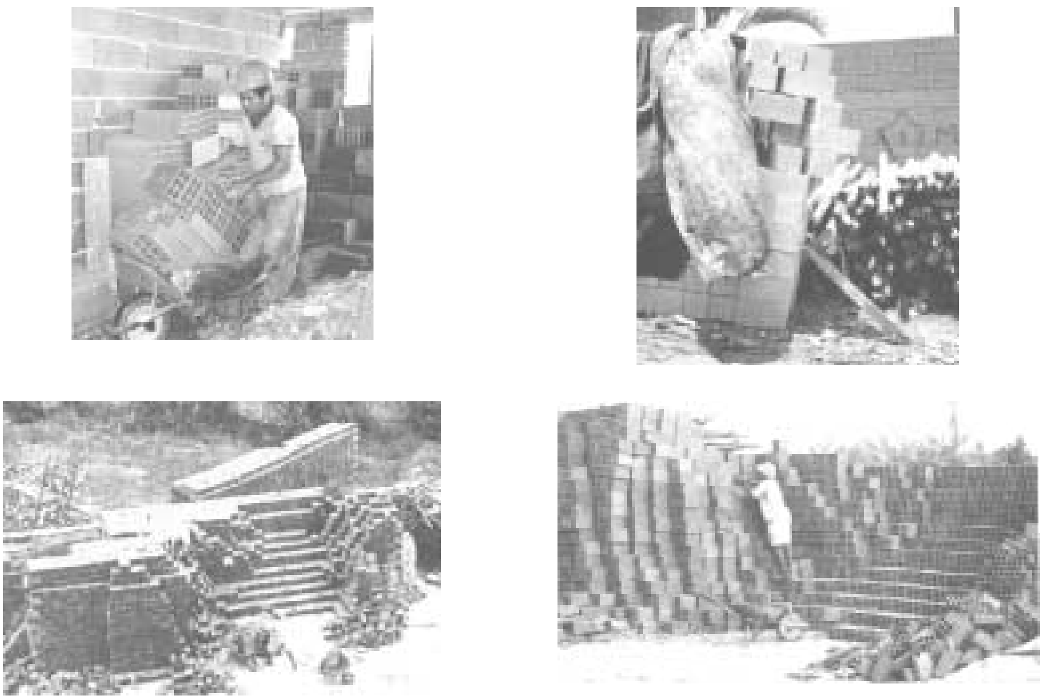


Figure 3 – Some factors inducing an increase in brick and block waste.

2 Case study context

2.1 Sustainable construction as a goal

Several meetings, papers, policies and laws have pointed out the building construction process must be improved in terms of reducing the environmental impacts it implies. For example, the Brazilian Construction Industry demands an amount of material more than one hundred times bigger than the amount demanded by the Automobile Industry. It also produces 2/3 of the urban residues (Pinto [5]) . Therefore, contractors should be induced to reduce material waste.

Both the new laws and the increasing awareness about these issues have provided a more demanding client in terms of building construction. The developers and the contractors realized that improving resources management is a must in the new context.

2.2 Concima company

Concima is a medium-sized developer-contractor firm that has a special interest in construction process management.

This company participated in another research project, as a partner of the University of São Paulo – USP, studying labor productivity. After obtaining the ISO 9002 certification, Concima set environmental preservation as a task to be accomplished.

In order to help the company to improve its environment management skills, without reducing its competitiveness, the Construction Department of the University of São Paulo (PCC-USP) was invited to develop a new site management approach to be used by Concima.

2.3 PCC-USP previous experience related to material waste management

The environmental impact caused by the construction activity is one of the concerns of PCC-USP. Over three years, PCC-USP coordinated a national effort, in 12 different Brazilian states, studying more than 100 building construction sites. This allowed ample and detailed diagnostics about material waste in the Brazilian construction activity.

After this study, a method providing a fast and continuous material consumption control (Andrade, 1999 [2]) was developed for many services/materials. So, the PCC-USP was prepared to develop a continuous process management to reduce material waste in the Concima building constructions sites.

This method, and the results obtained, are presented in this paper.

2.4 A partnership to reduce waste

The amount of material used in a certain construction task is influenced by several decisions taken by some agents, as one can see in Figure 4.

Figure 4 presents the agents involved in the Concima building site management .

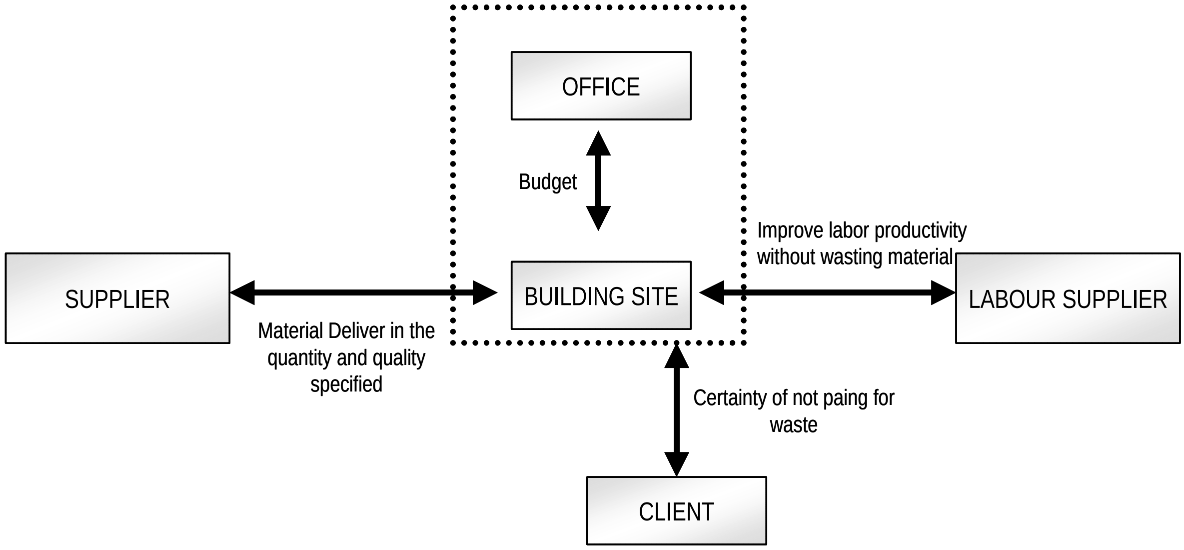


Figure 4 – The material consumption control and the relationship among the construction site and other agents involved in the constructive process.

3 Case Study

3.1 West Park Residential

The West Park Residential Project holds 452 apartments in 38,163.53 m². It comprises three 15-floor towers and four 17-floor towers. Each tower has 4 apartments per floor and each apartment has 2 or 3 bedrooms.

The structure of the towers is concrete walls, molded "*in situ*", and steel reinforced concrete slabs; the internal masonry adopts concrete blocks layed with multiple use mortar; the internal covering uses mortar render, in the cold areas, and gypsum plaster, in the other areas. The external covering will be constituted by a pigmented and texturized render.

The building site is very large and the access conditions are good. Trucks have access to the site interior. The material discharge is done by a tower crane.

3.2 Block work: execution and evaluation

Blockwork is a construction operation that generates a considerable amount of waste. More than that, the masonry units account for the major part of the masonry costs. Consequently, it is important to control blocks consumption.

Masonry, in the case study, uses concrete blocks and mortar. The concrete blocks are received and immediately transported up to the several building floors, where they are stocked and, later, laid by the masons.

The block waste evaluation was done by means of a sampling approach. A certain number of blocks ("A") were marked in the stock. After a week, the amount of marked blocks ("B") in the new walls (Figure 5), and the remaining market blocks in the stockpile ("C") were determined. Waste was calculated as: ((A- (B+C))/A)*100.

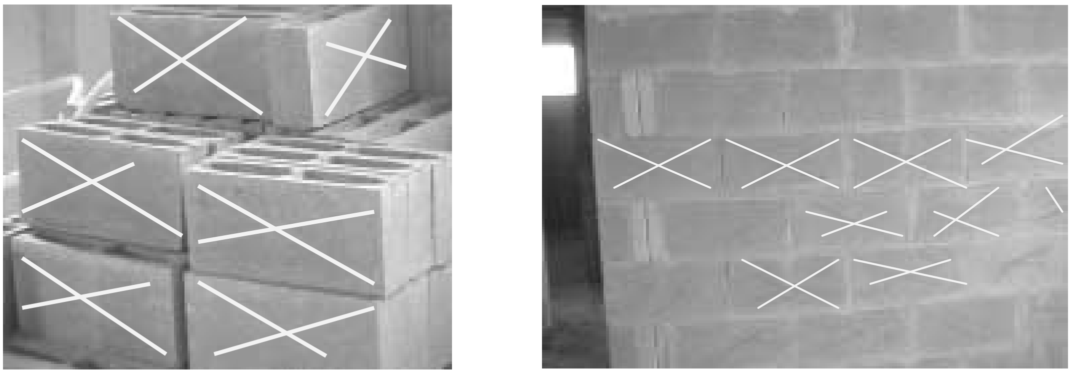


Figure 5 – Marked blocks in the stock and in the wall

3.3 Defining a target for the blocks consumption

Brazilian construction sites presented MLP values running from 3% to 48%. The case study site and process management was defined in terms of becoming similar to the sites which MLP were close to the minimum value, that is, 3%.

Once the Concima site managers agreed in establish a consumption process as close as possible to the defined one, Table 3 indicates the consumption rate the authors considered to be feasible to reach in the case study. The index was adopted as a target to be addressed.

Table 2 – Target block consumption rate for the case study.

Material	Material Loss in Percentage (MLP)	
	target	**comments**
Concrete Blocks	Waste < 3%	The authors consider that it would be possible, as far as the material consumption management follows the planned actions, to reach a waste rate smaller than the one presented by the best national performance detect by PCC-USP in the former research (see Table 1).

3.4 Blocks consumption management

In addition to the initial meeting, when the target of reaching to a MLP smaller than 3% was established and the production process features were defined, once a week meetings were scheduled.

Every Friday, a meeting was held to review the performance of the waste reduction strategy, against the initial targets

3.5 Results and analysis

The authors participated in 6 meetings before leaving the task of continuing reducing material waste to the site managers.

In the first meeting, as stated before, the target MLP was defined; more than that, several recommendations were placed in order to define good practices and human motivation to minimize block waste.

In the next five weekly meetings, the week MLP was calculated (see Table 3) and all the participants discussed it and planned actions for the next week:

- cycle 1 – showed a very good MLP; the authors believe that the first meeting influenced the foreman in his efforts to prevent the workers wasting material;
- cycle 2 – presented a bad MLP. The reasons for this unexpected performance was the workers turnaround. For the next week it was recommended to improve the new workers' training;
- cycle 3 – showed a good performance again;
- cycle 4 – was not as good as it could be. Problems with the masonry design were detected: the upper parts of the doors (Figure 6) and windows were not correctly defined, and several blocks had to be cut to fit to the walls dimensions. A new design definition was provided to fix this mistake;
- cycle 5 – again, bring MLP to the expected level;
- cumulatively, the MLP reach 3.2%, and the managers believed next weeks would be good. They expect the final goal (MLP $\leq$ 3%) would be met.

Table 3 – Results of concrete blocks waste

Cycle	MLP
1st	0,60
2nd	6,51
3rd	1,65
4th	3,80
5th	1,71
ALL	3,21

Every week, in a meeting, new directives were established to improve the rates detected.

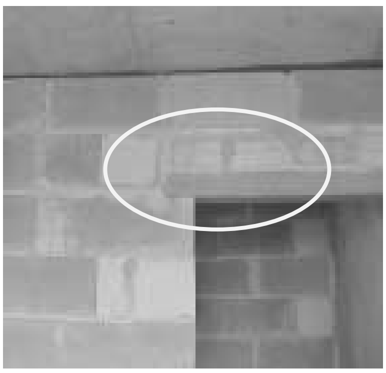


Figure 6 – Concrete blocks cut on top of door.

4 Final comments

The proposed method proved to be easy to use. The "decision based on figures" approach was approved both by the site superintendent and the foreman. The masons also were able to understand the goals and to accept the target MLP as their target.

The method also demonstrates the importance of reducing material waste. In the case study the MLP value, during the six weeks the work was tracked by the authors, was as small as the minimum national MLP previously detected. And we believe the final performance would be even better providing the approach to manage blocks consumption kept on being adopted.

The ideas presented in this paper have been successfully used by some researchers of PCC-USP, in other case studies, not just for block work. The authors believe that confidence in terms of the reachable performance and its continuous evaluation can provide a strong tool to help construction managers to reduce material waste.

5 Acknowledgements

The authors acknowledges FINEP, SENAI and CAPES by their support to the ongoing research effort to reduce material waste in construction.

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Analysis of subcontracting in Brazilian civil construction and guidelines for management of the safety and health of the work

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Abstract

It is very common the practice of subcontracting in civil construction, that is, services transfer to specialized companies. Even so, the management of the site still have several difficulties of management of the subcontractors. Safety and Health Civil Construction Brazilian legislation (NR-18) presents the exigency of the implementation of a "Conditions and Environment of Work in the Industry of the Construction Program" (PCMAT) that attends the safety's effective improvement and organization of the site. However, not always the needs and the subcontractor effective presence are considered in its development, because, many times, the company to be hired is not defined yet. Thus, the contracting company should fasten rules, according to the legal guidelines, to be followed by the subcontractors, such as, workers' participation in the integration phases and training of safety and health of the work. This paper presents the guidelines of subcontractor organization on site seeking, among other aspects, the safety of the work environment and the preservation of the worker's health. Another approached subject is the search and development of Quality Management Systems. All the other companies, present in the site and participating in the supplies chain, besides the contracting company, should be considered in the planning of the construction.

Keywords

Occupational health and safety; construction quality; subcontractors; building site.

1 Introduction

It is known that in the building site there are several teams working at the same time. Thus, several attitudes should be taken to facilitate the development of the work. Frequently contractors delegate to subcontractors portions of the construction services.

After formalized the subcontractors’ hiring, the following phase is the execution of the service. To have a no-problem development it is important to have a planning of this execution process. The organization should seek to the best form of resources allocation and the management of the subcontractors. The tasks of each subcontractor should be systematically obtained regarding the work and the other companies. The inspection and control activities of the subcontractors should also be programmed in a way to do not exist any superposition. The contractors should adopt a control system of costs to facilitate its management. The programming should constantly be reviewed in order to avoid flaws in the process.

At that rate, given the great variety of stages to be managed, Serra (2001) proposes, from a traditional model of management, an organization of the subcontractors in the building site. The proposed process should happen during the whole development of the decision's process and management of the subcontractors. It happens since the beginning of the selective process when it occurs the initial verification of the existence of registered and qualified suppliers for a certain service, passing by the contract elaboration, organization and gauge of the results gotten in building sites and concluding with the quality evaluation of the technical attendance service.

As the building site is a very dynamic and flexible structure, according to Tamaki (2000), to have organization in it, it will be necessary to guide the project through four basic principle: discipline and understanding of workers, programming of the activities, organization of the work and hierarchic character of the work.

According to Baxendale; Jones (2000), construction work covers many activities, techniques, materials and hazards and it is this diversity that increases the probability of accidents' occurring. An underlying belief is that the majority of accidents are not caused by careless workers but by failures in control which ultimately is the responsibility of management. Improved health and safety management systems are assumed to make good financial sense and should be part of the cost conscious culture of companies dedicated to efficiency and profitability.

It is in a position of distinction now, as one of the specialists and international committees main guidelines, the adoption of a Management of an Integrated Systems of Quality, Environment and Safety and Health of the Work during the accomplishment of the project (Alves Dias, 2001). Based in to the norms ISO 9000:2000 (Management of Quality Systems), ISO 14000 (Management of Environmental Systems) and BS 8800 (Management of Safety and Health of the Work Systems) a tool of project management is developed having as main guideline to assist the customers of each one of the norms. In the quality case: to the internal and external customers of productive process; in the environment case: to the whole society and to the environment in general; and in the safety case: to the workers, the ones who really participate of the productive cycle, giving them, besides the basic conditions to a safe work, citizenship and respect.

At that rate, it is believed that the organizational structure made for an management system will serve as a support for the management of the other ones, considering the integration of all the intervening players in each project. According to Alves Dias (2001), the systematic implementation of management systems integrating the subjects of environment, quality, safety and health of the work in the construction projects demands specific forms of performance.

2 Methodology of the research

This paper presents some conclusions of Serra (2001) that presents guidelines to the subcontractor's management in the civil construction. The subcontractor's management process is understood as a systematic that guides the programming, organization and control phases of the several intervening that settle down in the relationship among contractor and subcontractors in a way to define conditioners to minimize the conflicts and to maintain the conformity of the established agreement.

A self-completing questionnaire was elaborated with 62 multiple choice questions contending the main referring aspects to the subcontracting decision and to the subcontractor's management, including the safety and health of the work subjects. The questionnaire was sent for 30 building companies, being 50% the percentile of answer. In parallel, interviews were developed with 5 building companies and 2 subcontractor's companies to verification of the applicability of the proposals guidelines. Some contributions are transcribed along the paper to illustrate and to justify the conclusions and recommendations.

3 Safety and health of the work legislation in the building site

The new Regulating Norm 18 (NR-18) denominated Conditions and Environment of Work in the Industry of the Construction (Brazil, 1997), introduced innovations that appear from the own title and enlarges its application field for the whole work environment and not only for the building sites or services fronts.

The great contribution of the NR-18 revision is the introduction of the previous planning of safety and health measures of the work through the "Conditions and Environment of Work in the Industry of the Construction Program" (PCMAT) and the emphasis to the training aspects and qualification of the labour of this section. According to Barros Jr. (1995), "to plan the development of a work, still in the projects phase, includes from this time on, all the safety items. To Gantt chart the work starts to incorporate the need to foresee the measures of collective and individual protection and labour's qualification of each different phases".

The documents that integrate PCMAT are:

- memorial of the conditions and environment of work in the activities and operations, taking into account risks of accidents and work diseases and their respective prevention measures;
- design of execution of collective protections in conformity with the stages of work;
- technical specification of the collective and individual protections to be used;
- implantation Gantt chart of the preventive measures in PCMAT;
- initial layout of the building site, contemplating, besides, measurement prevision of existence areas;

- educational program contemplating the thematic of prevention of accidents and work diseases, with its hourly load.

It is stood out that the PCMAT should be available to the inspection and to be maintained in to place of the work for the managers', engineers', master builders' and entrusted permanent consultation. Each stage should be conceived being taken into account the potential risk of the activities and tasks. For that, it should be result of a work systemic among planners, budgeters, professionals of the work safety area and others, that should plan the execution of each phase of the work together.

However, an agent many times forgotten is the subcontractor, because its participation is not usually defined during the project phase. Thus, many of its needs are forgotten during the safety's planning.

To better disclose safety's specific practices and the conclusions concerning alterations and recommendations in the norm the bulletins denominated Technical Recommendations of Procedure (RTP) were created. Nowadays there are two regulations already approved: Protection measures against height falls and Movement and transport of materials and people in the work elevators. There are, still in study process, the following subjects: scaffolding, suspended chair, container, circular saw, biddings and Internal Commission of Accidents Prevention (CIPA).

The accompaniment of the occupational health and safety program should have as objective to do the necessary adjustments eliminating conditions of existent risks. The accomplishment of periodic meetings should be foreseen with all involved for the revision, the definition of priorities for future actions and for the establishment of new objectives. For Moreira Lima Jr. (2000), the program conception of the proposal form for the Brazilian legislation, determining larger importance to the measures of collective control and larger recognition of the risks in the work environment advances the world tendency of treating safety and health inside in the work subjects in a wide and foremost way inside the managerial system of the company.

4 Guidelines for the formalization of the subcontractor's hiring

The several professionals' association in the execution of the projects of the civil construction is facilitated by the systemization of organizational routines and by the use of tools that integrate these agents. This way, the contract should be considered as a managerial instrument that facilitates the acquaintanceship and the organization of the service in the building site. This benefits both parts, because each one possesses its expectations that need to be previously cleared up (Thomas *et al.*, 1994; Uher, 1991).

The process of formalization of the hiring should be surrounded of cares that provide a better elucidation of the contractual conditions, which does not always happens. The non existence of this concern can be considered a negligence that cannot be admitted in a commercial relationship among serious and mutually respected companies.

It is observed that some companies try to develop models of standardized contracts that contains the main assimilated guidelines of the reality and managerial practice. This becomes viable, mainly, for the companies that maintain the same constructive system and a standard of work. Thus, they give more dynamism to the process.

However, when differentiated or special conditions are desired, just as the development of a technology, it should be made a more specific discussion about the expectations of the implantation, the need of changing the traditional form of execution and the commitment with the established requirements. This way, there is an intend to analyse all the necessary conditioners in advance in a way to do not remain any doubt on the process and, in the same way, to detach the penalties and attitudes in the unconformity case.

Another special condition happens with the creation of the partnership, in which are established philosophies and differentiated treatments of solidary relationship among the parts, besides the compartment of goals and reached results. But it is important that the companies continue registering the formally established agreements.

The contract should objectify the elimination of conflicts and judicial disputes, trying to clarify solutions in advance. Serra (2001) proposes a contract model where 16 clauses are striped. Among them, it is possible to meet the referring clauses to health and safety of the work, inspection forms and control of the execution quality.

The clauses about health and safety of the work should seek the understanding of the subcontractors front to the legal demands of inspection of the work conditions and its legal responsibility for its own workers.

One of the demands of PCMAT, is that the workers' training, can be assumed by the contractor, mainly in the cases of partnership. Another demand, is the use of Personal Protective Equipment (PPE), should be detached to the subcontractor, as in one of the observed cases: "the subcontractor should guide its workers for the correct use of PPE".

To avoid problems for the contracting party as for the contracted one, in case of accidents or of inspection of the Ministry of the Work, those need to maintain in its ownership a greeting term of the integration training to the work signed by the worker, besides the term of PPE greeting. It is also important to attach a copy of the PCMAT to the signed contract or to do a note of greeting of the contract to be signed by the subcontractor.

To guarantee the conformity and quality of PPE, some contracting companies supply them directly to each subcontractor worker and discount the corresponding values during the payment of the services. Other companies, to protect themselves even more describe clearly which of the PPE types that are necessary for the contracted service. A contract model studied contract describes the equipments for the service of establishment of floors and granite toilet seat covers, declaring that "obligatory PPE to be used during the accomplishment of the work are: safety rubber boot, protection glove, hard hat, safety glasses, hearing protecting, facial protecting, breather with filter".

Other important norms that are not always mentioned during the contracts elaboration phase concern to the Medical Control of Occupational Health Program (PCMSO) and to the Environmental Risks Prevention Program (PPRA). PCMSO includes also the obligation of the admission and periodic medical exams of the present workers in the building site. The risks of accidents to which the workers will be subject in that work and specifically in the service should be contemplated by the PPRA.

It can be requested, when there is a worker entrance in the work, a recent copy of the Occupational Health Certificate (ASO) and of the training admission certificate by the subcontractor. In this training the workers must have been instruct of the inherent risks its professional function. Besides, by the time of its entrance in the building site, he will pass by a new training given by the work safety technician of the contracting company. Considering the case of great personnel hiring, as in the structures service, it can also be requested that the subcontractor indicates a representative to compose the CIPA commission.

It was verified that some subcontractors are conscious of those demands, because they hire specialized companies to make the medical exams and emit the employees' ASO. When the workers of those firms come to work in a work, they bring with themselves the vouchers of their exams, and they already shown themselves physically capable to assume its work position.

5 Guidelines of health and safety of the work

According to Lingard; Holmes (2001), occupational health and safety risk management is described as three-stage process. First, hazards in the work environment are identified. Second, the risk posed by these hazards is assessed and, finally, appropriate controls for these risks are identified and implemented. Technological control measures, such as the substitution of hazardous substances and process or the implementation of engineering controls, are preferable to individual controls such as the introduction of the use of PPE.

The contracting company should have a management of safety program that contemplates the several types of hiring that happen in the work. Or rather, it should seek its workers and also to the subcontracted labour.

Wilson Jr.; Koehn (2000) also detach that the contracting party can take the responsibility on the safety management of its several subcontractors, which does not mean that he should assume the obligation on the implementation of the program, but that he should have a good knowledge of the safety procedures of each specialty working in the building site to be able to inspect it.

Each service has particularities and that generate its own risks of accidents. According to Hinze; Pedersen; Fredley (1998) the specialties or the professions that most suffer accidents are the electricians, the equipments operators, the workers in height, the plumbers and the carpenters.

According to Rodrigues (2000), the largest indexes of fatal accidents in Brazilian civil construction industry happen due to the fall, accidental impact by the fall of an object, accidents caused by machine, burial, motorized vehicles and electric current. But, those data cannot portray the reality correctly for two correlated reasons: first, because there are some accidents that are not communicated to the official organs; and, in second place, because of the great number of workers working without registration.

For Hinze; Pedersen; Fredley (1998), the knowledge of the causes contributes to avoid or to decrease the indexes of work accidents in the civil construction. Besides, some of the accidents causes are peculiar of certain specialties and they could be avoided with an directional training. Thus, for certain functions, the training by the entrance time or in the periodic training can be more intensive seeking the reduction of the risk.

Rodrigues (2000) stands out that the researches in the section revealed that the origin of the accidents is conditioned to the lack of absorption capacity of the foundations transmitted in the trainings and to the difficulty of reading the posters and warnings of safety. For that reason, some companies try to base its training in the line of the workers' basic literacy.

Some employer institutions tries to give technical support to its filial companies through the development of a special training program of the teachers' that will give literacy classes for the workers during the maintenance period of the building site.

A lot of companies start to create study and training environment, including safety and health aspects, inside of the own building site as an incentive and engagement form of the workers. For Wilson Jr.; Koehn (2000), the best training in safety of the work is the one acquired through the experience of the training in the own work place and of the continuous education.

Thus, knowing about the needs and difficulties of its subcontractors, some manufacturers try to engage them inside of theirs safety and quality programs. It is the case of one of the interviewed contractor. According to the engineer, "the subcontractors workers are treated as our employees. Every week they stop about half an hour to receive training with our workers. One week the theme turns on safety of the work and, in the other week, about quality. It is the quality’s moment and the safety's moment. (...) We also have a literacy school for workers inside of the company, including the subcontractors partners' workers".

According to Wilson Jr.; Koehn (2000), the excellence results of a safety program can be observed through the auditors' of safety of the work inspections. It was observed that the more frequent it is the training in safety, the more frequent it is the application of its results in the daily of the work.

The intensive use of the labour and the quite aggressive work environment, engender a high physical waste of the workers and series of the correlated diseases, making clear that the lack of a good infrastructure in the building site formed an allied to the inherent alimentary lacks of that group predispose them such to the illnesses as to the accidents.

According to Lichtenberg (2001), the most frequent work diseases in the civil construction area are: hearing loss, dermatitis, lesion for repetitive effort (LER), ophthalmologic problems, pneumoconiosis (especially the silicosis) and intoxication by lead (inks components).

Lingard; Holmes (2001) suggested that employers should bear the responsibility for providing protective equipment such as gloves, hats and sunscreen. They suggested also that the responsibility to provide training lies with the government, trade unions, employers and principal contractors.

Thus, the question of health and medicine of the work should also be discussed emphatically as long as basic aspects, as the appropriate cleaning of hands and feet before putting on gloves and boots are fundamental for the preservation of the worker's health. Likewise, strategies to the conscious and to the combat to the alcohol consumption should be created, above all in building sites, where it should be prohibited.

Due to the difficulty of the companies in maintaining management systems working inside of its organizational structure, Tait; Walker (2000) suggest the use of external audits. The benefit principal include positive feedback for the health and safety professional that could lead to acknowledgement by senior management of their contribution to the health and safety performance in the organization.

6 Guidelines of the quality execution control

The main objective of the execution control is to substitute the individual control for a formal process of collection of information. For Souza *et al.* (1996), the "checking and inspection of the executed or in execution service, with the respective corrective actions in cases of no-conformity avoid the deviation of the direction and guarantee the normal course of the work". With that, it is obtained the transparency of information that should be looked for during the management of the work. For Koskela (1992), the transparency lack in the constructive process increases the propensity to the mistakes, it reduces the visibility of these mistakes and decreases the motivation to improve.

Other important repercussion of this systematic is that the development and application of the beginning of transparency are related with a cultural change of the organizations that passes to manage its production systems through a more effective participation of the workers. Thus, the workers should be correctly instructed about the execution method of the service and how the service will be evaluated.

When the service is delegated to the subcontractors, the quality standards demanded by the contracting party should be clearly specified. The indication of approval requirements of the service and its tolerances should be something plenty clear for the workers and instructor of the subcontractor. During the quality evaluation of the service, the contracting party auditor should also know how to proceed in the case of non-conformities and how to guide the corrective actions. In the accomplished research, the most frequent auditors to the activities of the subcontractors are: the engineer, the master builder or its entrusted.

For each service, it should be detailed described the systematic of control: when make the control, who accomplishes it, how to measure, how to measure, how to make the control, how to correct. Each subcontracted service should have its own schedule of execution procedure and quality verification, with the judgement parameters and values of tolerance, with a field to identify the responsible person for the approval.

In the accomplished research, it was identified that most of the companies accomplishes inspections through systematized schedules. The observation frequencies varied in function of the type of the service, could be daily, weekly or monthly. The periodicity of the evaluation should have been combine during the negotiation of the hiring, and it can coincide or not with the measuring stages. But the ideal is that the quality execution evaluation accompanies the service more closely.

The engineer of one of the researched contractors detach that in its company there is a very rigorous standard of quality requirements evaluation. If a tolerance is surpassed, it is common to order to remake the service and the contracting company does not bear the burden of any current damage of that fact. The subcontractor should assume the whole obligation due to the remake of the service.

Considering now the question of quality of the materials, the contractors should also prepare schedules of receiving control of materials, according to the requirements of the specification. Besides, they should instruct their workers to receive them correctly, even when they would be supplied by the subcontractors. The contracting company should evaluate the quality of the material in a way to authorize or not the incorporation of these in the work. However, this quality control of the materials’ can be substituted by certificates sent accredited entities.

The maintenance of the equipments used is also other important inspection item, that needs to constantly be checked because of the possibility of been the cause of problems of work interruptions. When the subcontractors hiring happens with the supply of the equipments, the degree of expected acting it should be specified.

7 Final considerations

It becomes necessary, for the survival of the own company that a change happens in the traditional mentality for a new organizational and cultural posture in relation to the organizations that collaborate in the development of its product. The guidelines proposed try to alert the professionals that did not become aware of the importance of the relationship improvement with the subcontractors yet, aiming, among other things, to acquire more competitive advantage.

In spite of its importance the integrated health and safety management of the work, environment and quality was not observed in the researched companies. It is believed that happens because the safety's management and the environment is still an item not very explored by the companies as market strategy. Besides, the potential customers are more concentrated in the collection of quality management systems. Now in Brazil it is in detach the demand of credential of the building companies in qualification programs to participate in public biddings.

The improvements in health and safety of the work happened, are usually results of initiatives of the companies created after campaigns of conscious made by the government and the severe inspection of the Work and Employment Ministry. Just in some big cities few companies are trying to implant safety management systems.

It was verified that the subcontractor’s posture regarding the safety an the health of the work and quality management depends on the collection and inspection of the contracting part. Some companies, about 80% of the researched companies, have as requirement for the contraction the definition of one specific clause about the safety and health of the work. In this agreement the responsibilities of the safety management are shared, and the obligation of each part are exactly defined. However, at any of the researched projects was identified as a requirement for the contraction the presentation of index of work accidents occurred with the subcontractors. The safety’s inspection happens every week at the works made by the subcontractors.

Usually, the subcontractors are micro or small companies that do not have organizational structure to manage these processes. It is also observed that the contracting part, many times, assumes the role of being a partner that provides the conditions for the development of the providers of the serial industry. For this, the subcontractor should allocate resources that facilitate the management and development of the process. This way, the contracts tend to be signed for longer periods of time that increase the promise and allow the return of the partner’s investing.

Other important analysis regarding to the recognition of the worker's importance for the good acting of the enterprise. The companies start to create motivation programs, professional formation and educational learning as a form of qualifying the labour in the civil construction section. The employee of another company, or rather, of the subcontractor, becomes to be considered as a partner of the contractor. The companies start to link with its partner in a cooperative form, where the success of one depends on the success of the another.

It was verified that the investing done in the improvement of the safety and the health of the work returns to the companies like more productive and motivated workers. This is possible due to the better quality of life on the environment of work, with consequent recognition of their dignity as a human being.

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The subcontracting strategy and its influence on the work environment of civil construction

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Abstract

The building companies are used to practice of subcontracting a lot to obtain a larger flexibility and control of the costs involved in the construction process. These companies transfer, sometimes of messy form, the execution and supply of materials for subcontractors. This work developed in the city of São Carlos, interior of São Paulo, seeks to analyse how it is made the selection and evaluation process of those subcontractors, as well as to analyse if they have any type of quality system, if it is made contract among the involved parts and how they work with the question of health and safety of the own and subcontracted labour.

Keywords

Subcontracting, subcontractors, labour, Health and safety

1 Introduction

Due to its great participation in the Brazilian internal product, around 15%, the civil construction represents one of the largest sections of the Brazilian economical activity, being still responsible direct and indirectly for an enormous portion of the employments generated inside of the country.

The civil construction chain is constituted by several sections, being the construction section responsible for the largest contribution inside of civil construction, around 10% of the internal product, besides being the largest generator of employments inside of the chain. That section is constituted in your majority by micro and small companies, they possess less than 49 employees.

The building companies act directly in the construction subsector, being responsible for the execution of the services, which are revised in the most of time to the subcontractors. Several factors justify that transfer, such as skilled labour lack, production flexibility, easiness control of the costs, improvement of quality, smaller administrative team, decrease of financial and labour risks and, mainly, smaller production costs.

This transfer of service between buildings companies and subcontractors is denominated subcontracting. In Brazil, it is observed that, most of time, the subcontracting is made in a messy way and without the contract establishment between the parts. It is known that the contracting part should look for that company that can add more value to your product.

It is verified that the subcontracting practice is very common inside the civil construction all over the world.

The existence of specialist firms in the execution of services, or packages of services is one of the principal characteristic and advantages of the North American civil construction industry, according to Bennett (1991). Each one of the contracted specialists projects produces or organizes the materials and components supply and builds a different part of the building. The development of the section is highly dependent of those specialists' and of the popularisation and standardization of constructive procedures.

According to Furusaka (1991), in Japan the subcontractors form a structure denominated "organization of exclusive subcontractors", constituted by specialist firms in several services, as formwork, frames, structures reinforcements etc. The other subcontractors are used by the firms to guarantee flexibility and the variation of construction demand. The autonomous workers represent less than 5% of the labour. During the selective process of subcontractors, the buildings companies don't consider only the price of the contract, but also the operational ability, the trust, the capacity to develop project, the easiness of settling down communication etc.

To Winch (1998), the subcontracting index in civil construction industry presented a notable growth rate in the last 30 years. This due to the strategic decisions of the companies that sought keep the flexibility and the productivity of the production. The subcontracted specialist is also present in the organizational structure of British civil construction companies and it is one of the principal responsible for your development. Your participation is integrated and requested since the project phase.

Serra (2001) mentions that the subcontracting companies provisions the work with the necessary human resources in some moment and they contribute to reduce the risks associated to civil construction.

To Villacreses (1995), the main reasons to subcontract are: variability of demand, insufficient amount of works to keep own teams, maintenance of lower administrative costs and reduction of supervision problems. Other reasons found with smaller frequency are, bigger productivity, reduction of labour work problems, better previsibility of the costs etc.

So, this article has as objective analyse how the process of subcontractors administration in Brazil is made, identifying aspects as: existence of quality systems, how the contract is made between the involved parts and how is made the administration of health and safety of the own and subcontracted labour.

2 Case study

The research accomplished in the city of São Carlos, interior of São Paulo State, Brazil, entitled "Subcontracting in the civil construction in the city of São Carlos", has as objective the elaboration of the buildings companies profile in relation to the subcontracting practice. It was looked for information regarding the selection and evaluation process of subcontractors, the type of contract between the parts, and others. It was also verified if the contracting company possessed Quality System, if it was made the workers' training and if they considerate the subcontractors needs, how the company treated the non conformities of the service and how they worked with the administration of safety and health of the own and subcontracted labour.

2.1 Methodology

Initially it was made the raising of the building companies which have more involvement in subcontracting practice in the city, through the solicitation to the Town hall of a list of building companies registered in the city of São Carlos. In spite of the great number of registered companies it was verified that many were not more in operation. So, the most important building companies were identified and visits have been scheduled to the same ones for interview and application of a questionnaire regarding the subcontracting practice.

That research counted with 14 companies that accepted to participate in the interviews and to answer the questionnaire. Among those companies, 5 are micro companies (with less than 9 employees), 7 are of small companies (between 10 and 49 employees) and 2 are considered average companies (between 50 and 99 employees).

The applied questionnaire was reformulated tends as base the questionnaire used by Serra (2001). After reformulation, the questionnaire kept the possibility of multiple choice, arranged in a total of 71 questions, subdivided in six parts. The first part embraces the characterization of the company and it contains 13 questions. The second part refers to the strategy of subcontracting and it contains 5 questions. The third part is related to the evaluation and selection process of subcontractors, arranged in 20 questions. In the sequence, the fourth part verifies the process of contracts establishment and it contains 10 questions. The fifth part tries to observe how the organization in the civil construction is made in the presence of the subcontractor and it contains 15 questions. Concluding, the sixth part discusses the performance evaluation process of subcontractor and it contains 8 questions.

3 Data analysis

To facilitate the data analysis it was elaborated a spreadsheet to contain all the answers marked by the interviewees. In that way, it can be obtained a percentile value that reproduces the reality of the civil construction in the city of São Carlos. Analysing the interviews and each grouping of questions, as mentioned previously, it is obtained the conclusions about the identified objectives.

The data here demonstrated were retired from the partial report of the scientific initiation research (Branco Jr., 2002), where anyone can have access to the spreadsheet with all referring data analysed in the research.

It was verified that the subcontracting practice is used a lot in civil construction in São Carlos, 100% of the companies interviewed use subcontracted services. The main observations considering the health and safety of the work aspect are describe below.

3.1 Selection and evaluation process of subcontractors

The selection process begins, most of the time, with a realization of a bidding process of subcontractors. The building companies make an invitation for a pre-selected group of subcontracting companies.

The bidding process, for Shash (1998) is originated when the contracting party prepares a dear cost of service to be executed by your own workers and after that, they requests several quotations to subcontracting companies. The contractor settles down a period for elaboration and presentation of the proposals. The interested agree with certain pre-established rules and they submit the price of your service to the contractor.

It was considered in this research that the phases of the process are: requisition of the service with the subcontractors, selection (including proposal evaluation received by the company) and the contracts establishment, where the principal aspects are discussed between the parts.

A few companies worry about the safety question in the selection or evaluation phase of subcontractors proposals. Only one of the interviewed companies answered to observe the norms of health and safety in the definition of the service. Sometimes this concern is limited, the companies put a restriction to the number of workers that can work at the same time in the construction. They use this practice to avoid that they reach a value that request the elaboration of safety's project or surpass the minimum conditions of existence in construction. According to the Brazilian legislation, Conditions and Environment of the Work in the Construction Program (PCMAT) it should be prepared for works with more than twenty workers.

The quality question is already treated with a little more seriousness in the process, because some companies consider that factor as fundamental requirement in the determination of the best proposal.

It was verified that doesn't exist only one professional responsible for those different phases of the selective process, being under the owner's direct responsibility in two companies. Either, a consensual understanding of the period of time considered ideal doesn't exist for the development of those phases. Some services, as hydraulic installations, painting and conditioned air, possess the periods varying between 19 and 35 days of duration for the selection process.

This process usually happens among a group previously selected by the building companies participants of the research. Approximately 60% said that is made an invitation or summons letter with the information considered more important for the formulation of subcontractors proposal. Among these information, the project and your specifications were considered as main information to be sent to the subcontractors for 93% of the companies and the physical Gantt chart of the work was mentioned by 57% of the interviewees.

After the subcontractors elaborate the proposals and send to the building companies, 65% of this companies make a pre-selection among the proposals received to give continuity to the selection process. In this pre-selection stage, some companies try to verify the juridical, fiscal, technician and economical-financial aspects of the subcontracting companies, through the solicitation of documents. The Table 1 summarizes which are the principal documents requested for the juridical, fiscal, technique and economical-financial qualification.

It is verified that there is no solicitation of work accidents cadaster of the company. When the contracting company possesses administration system of safety of the work, they can request information about the indexes of accidents happened with the subcontractor workers during a certain period of time.

Table 1 – Main documents requested to the subcontractors

Documents requested for the qualification		(%)
Juridical	The subcontractor workers registration	43
	Registration in commercial committee for legal entity of private right	21
	Creation of institution Law of legal entity of public right	21
Fiscal	Proof of cadastral registration	72
	Proof of regularity	64
	Registration proof in the cadaster of taxpayers state or municipal	43
Technique	Aptitude proof for acting	50
	Registration in the professional entity	43
	Qualification of the technical team members	36
Economical-financial	Patrimonial balance	29
	Accounting demonstrations	22
	warranty parcels of the contracted service	22

In spite of most of building companies realize that pre-selection, a great part of these companies only request the subcontractor workers registration to avoid labour problems in the future. Practically a quarter of the companies answered that already had labour problems due to the fact that the subcontractor have not registered your workers and these ended up entering with labour action in the Work Justice against the building company and not against the subcontractor that had hired them. Together with the documents requested above, other factors considered in the analysis of the proposals are commercial, managerial, technique and price evaluation.

The principal parameters used by the contracting companies to accomplish the subcontractors selection are in the Table 2.

After complete the subcontractor selection, the analysis of the proposals is accomplished to identify which will be the subcontractor winner. The analysis tries to agglutinate all received information in order to identify the most appropriate proposal.

The financial question or the smallest price is still the great responsible for the definition of which will be the proposal winner. However, factors as quality and technical evaluation of subcontractors are also mentioned for almost half of the building companies, what makes have faith in a change of posture by contracting companies.

Table 2 – Parameters for subcontractors selection

Parameters for subcontractors selection	**(%)**
Definition of periods	92,9
Payment conditions	71,4
Interfaces with others subcontractors and own workers	42,9
Acceptable acting patterns	35,7
Constructive details	35,7
Project specifications	28,6
Division or delegation of responsibilities	21,4
Control points	7,1
Recommendations of changes	7,1
Other (price)	7,1

3.2 Contracts establishment

The contract establishment happens in practically all the building companies, only one of the interviewees said not realize this procedure. The contract should be considered as a warranty that the service will be executed and the payment will be made in the right conditions between the parts.

The main contractual terms used by the building companies explain the service description, aspects of safety and cases of fines, according to Table 3.

Table 3 – Main contract terms

Contractual terms	**(%)**
Description of the service	100,0
Safety of the work / supply of PPE	71,4
Arrears and fines for blame of the subcontractor	64,3
Contractual fines	57,1
Technical warranty of the service	42,9
Readjustments indexes	42,9
Arrears and fines for blame of the contracting party	42,9
Retention	14,3
Conditions of additions in the contracts	14,3
Priority definition in the case of ambiguity project X specifications	7,1

The safety and health question is put a lot in the contracts due to the existent of risks in the construction activity. The responsibility for the integrity and the worker's life is a lot of times shared between the contracting and subcontracted agents. So, these companies try to put terms that become aware the subcontractors and reduce your responsibility. Though, a lot of times that clause limits to the supply and correct use of Personal Protection Equipment (PPE) and, in some cases, expresses clearly the subcontractor compromising in assuming the risks associated to your workers. In spite of your seriousness, this question is not treated as decisive factor in the contracts between the building companies and the subcontractors.

Another observed factor is the existence of additions in the contracts that concerns increments of services and modifications of projects and specifications. It was verified that is not also common the contracts break. The principal judicial disputes with subcontractors happen in function of labour questions with the subcontractor workers and due to the non-compliance of the contractual terms.

The principal contract type used by the building companies is the contract for global price, in other words, the price of the work is stipulated before your beginning. 80% of the companies interviewees said that use this contract type.

3.3 Health and safety of the work

The companies should give a larger attention to the safety and health question as for theirs own workers, as for those subcontracted. Sometimes, the simple supply of protection equipments is left of side and the worker is forced to take a risk of your own life in the execution of the service.

So that the worker can execute your service without risk, it should be elaborated by the building companies or even by the subcontractor a project of safety for the building site. Unhappily, as it was said previously, PCMAT should be prepared for works with more than twenty workers. This, together with the inspection lack, does the building companies ignore the safety workers question.

The same happens to the workers' health, most of the work doesn't possess appropriate sanitary installations for the workers' health, in spite of the country has norms for this question. The inspection lack is certainly one of the principal reasons for this happen.

93% of the building companies said that they realize safety inspections in the subcontractor activities, most of them daily.

The recommendation of correction was mentioned by 80% of the companies as form of correcting the no-conformities found in the services. All the interviewees said that verified if the suggested actions were implanted.

As a form of increasing the workers' productivity, some building companies possess motivation programs of the labour, being the most common strategy to concession social benefits, as medical agreements and supply of food. This practice is used for approximately 35% of the companies.

To aid the subcontractors, that are usually smaller companies, some building companies develop partnership programs. They trained the subcontractor workers and aid your administrative organization, according to Table 4.

To Baxendale; Jones (2000), the contracting party should give support for the subcontractors in relation to the knowledge of the health and safety legislation of the work. The responsibility about the workers' integrity is own of the employer, but in many cases, it can reach the contracting party.

According to Serra (2001), the training can be united and contemplate safety aspects. Safety's courses can have a basic module and a more specific module related with services that involve larger risks and they present the biggest indexes of work accidents.

Table 4 – Aspects of a partnership program

Aspects of a partnership program	**(%)**
Subcontractor workers training	42,9
Aid to the administrative organisation of the subcontractor	42,9
No partnership program	28,6
United literacy with the employees	7,1
Support for conception of production projects	7,1
Integration of the quality system	7,1
Technology development	0,0

The performance evaluation, in spite not be formalized with frequency, is done periodically by the companies. These evaluations are made mainly by the master builder or for the engineers. The principal appraised items concern the conformity to the period and the quality of the service execution, according to Table 5.

The contracting companies usually measure the subcontractor performance, any building company possessed quality certificate, 14% only said that they possessed a quality system, however they didn't have interest in certification. The quality control of service execution was made through registers of verification of the services.

Table 5 – Parameters considered in the operational evaluation of the service

Parameters considered in the operational evaluation of the service	**(%)**
Conformity to the combined period	85,7
Execution quality control	85,7
Wastes control	71,4
Honesty and reliability	71,4
Correction of the found problems	64,3
Observation of the health and safety norms	64,3
Commitment with the service (verify if there is not privilege of other works)	57,1
Standardization of the work methods	50,0
Organization in the construction work	50,0
Conformity of the rendered service with the receipt	50,0
Personnel's productivity control	35,7
Attendance during the installment of technical attendance	28,6
Participation in the meetings	0,0

Among these factors, the quality control of service execution is considered as one of the most important to the building companies. However this control is not rigorous, since no company possessed certification. This control is made, most of time, for the master builder.

The observations of health and safety norms of the work were mentioned as being one of the principal parameters analysed in the operational evaluation of the service. Some companies worry about several aspects of health and safety, such as, the maintenance of existence areas in appropriate conditions of use, the installation of trays and periphery protecting, training in safety. However, other companies only limit to include in your evaluation the use, correct or not, of PPE by the workers.

All the data analysed by the contracting company are put in a database that seeks to form a cadaster of subcontractors to facilitate a new selection process. This procedure is adopted for almost 60% of the interviewed companies. Half of them possesses an computerized acquisition or cadaster system of service and just one answered that didn't possess any informal intern qualification system of subcontractors.

4 Final considerations

The analysis here presented is based on real data presented by the building companies of the city of São Carlos. The profile here demonstrated serves as reference for other Brazilian cities, because São Carlos is a medium size city and has a great technological capacity due to your academical and industrial nucleus.

Observing the great number of subcontracting services, it is verified that several companies are working at the same time in civil construction. Due to great amount of information to be processed, the reduction of the uncertainty and the coordination of several specialists present in the construction, the subcontractor contracts manager function is putting upon to the technological engineer's function. Therefore, Olsson (1997) proposes the creation of "subcontracts coordinator" position in civil construction, this person would be responsible for the subcontractors administration, besides for the health and safety question.

The payment conditions and the choice of the smallest price are still today prevail on the other parameters in the moment of analysing the price of the received proposals. Factors as life insurance for the workers are still a dependent item of the entrepreneur's understanding or of collective agreements that force your adoption.

The safety and health administration of the labour in the work should turn practical to be implanted in the construction. The creation of routines and safety procedures of prepared workers to become multipliers agents of improvement of conditions in construction, they are strategies that already work in some building companies. The transfer of these information to subcontractors becomes fundamental to reduce or until eliminating the conditions of accidents risks in the work. It is important that the contracting parties not just inspect the subcontracting services in quality and productivity aspects, but they also analyse the safety and health performance of the workers.

It was verified that the selection and evaluation processes of subcontractors are consolidating in the market as a managerial tool. That is due, mainly, to the understanding or implantation and certification of Quality Systems in the companies, with the consequent procedures of materials and services suppliers qualification.

Most of the building companies consider that the subcontracted workers have a larger productivity than the contracted workers and, besides, they use the partnership programs with subcontractors, supplying training for their workers. This evidence that the contracting part intend to form stable partnerships with subcontractors to acquire a better aid in the future.

It is important that the contracting and contracted part look for more efficient forms of united administration of your production, as a form of improving the companies performance, to reduce wastes and to obtain works with more quality and economy.

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Environmental performance of Brazilian general contractors: an overview

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Abstract

This article intends to show the stage of development of Brazilian general contractors, according to the environmental influences of the activities processed on-site, and also organisations' behaviour concerning them. This paper describes the results of an applied questionnaire and some contractors' considerations presented on national and local meetings that have taken place during the author's ongoing research named "Study of environmental management systems' applicability on building contractors". It was found that some Brazilian contractors have shown concern on these issues and have made some advances. However, most of them are not aware, and will remain as that until an external factor pushes them to change.

Keywords

Environmental performance; building contractors; environmental aspects; environmental impacts; environmental management system.

1 Introduction and methodology

The inefficiency of the usual model of development practised by industries all over these years, regarding the environment, is a matter of fact. Their behaviour is currently questioned because the environment must cease to be considered as an endless provider, and it cannot absorb all the waste generated by economic activities. This is also true to construction industry, where organisations are more and more obliged to remain competitive while being sustainable.

In this context, the analysis of the Brazilian general contractors' behaviour appears as an important point to be discussed and is the major objective of this article. Their activities, and also their products, interact with the environment in many different ways. This article considers their major negative environmental interferences, pointing that there are already solutions available to control and to minimise them.

Another point that justifies the necessity to take an overview on Brazilian contractors' environmental performance is the tendency of increasing regulatory demands and financing programs restrictions, in this country.

This article focuses on the environmental aspects of contractors' on-site activities[1], describing them and also the existent pressures to control them.

The contractors' environmental performance analysis results of an investigation concerning two general contractors. The data were obtained throughout an applied questionnaire and considering, also, other contractors' deliberations presented on national and local meetings that have taken place during the author's ongoing research named "Study of environmental management systems' applicability on building contractors".

The questionnaire contemplates the aspects suggested by the ISO 14004 "Environmental management systems – General guidelines on principles, systems and supporting techniques" and probes contractors' existing environmental practices, including their difficulties when attempting them. It also contemplates their performance and maintenance of quality aspects, including documentation, internal communication, legal and other requirements, thus evaluating contractors' basis in case of a potential integrated management system implementation.

The two investigated contractors were chosen as their management system can be considered as "good practices" and they already consider the environmental issues. Contractor A builds non-residential buildings, works in many Brazilian states and has international companies as clients. Contractor B has 5 ongoing construction sites in Sao Paulo and works mostly with residential buildings.

Finally, the information presented here, as well as the conclusions which we can withdraw, concern the Brazilian reality; nevertheless, some of them can be extrapolated to other countries.

2 Environmental aspects of contractors' on-site activities

Contractors' activities developed on sites may cause many environmental interference such as: generation of solid and liquid residuals; consumption of non-renewable natural resources; removal of the vegetation (erosion); generation of noise and vibration; sedimentation of storm sewer or receiving streams; air pollution with dust and particulate matter; wasting of materials, water and energy; inadequate disposal of residuals; disposal of renewable sources; interference on the hydraulic and drain systems.

Among these environmental interference, the large volume of solid residuals disposed on urban environment and the large consumption of natural resources are the most relevant ones and that must initially be taken into account. The interference related to harmful effects like noise and pollution represent a second level of requirements, and they were not treated here. Nor either the aspects related to the water and energy consumption during the construction phase.

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[1] The design and planning considerations that can influence the buildings' environmental performance as a product were treated on Degani & Cardoso (2002).

2.1 Solid residual generation

The large amount of solid residuals that have been generated and disposed on the urban environment is the heaviest negative environmental aspect of civil construction activities concerning the construction phase. The characteristics of materials and the applicability processes lead to the occurrence of loss - especially the share that comes from waste. In Brazil, Andrade *et al.* (2001) consider that the residuals generated on building sites represent approximately 5 percent of the finished building, concerning mass.

A list of environmental impacts of the incorrect disposal of construction and demolition residuals on the Brazilian urban environment can be found in Pinto (1999). The author considers as impacts from soil pollution to fuel burning occurred on their transportation to landfills.

These wastes are composed by materials coming from different sources, presenting different characteristics that may cause, also, different impacts on the environment. Despite that heterogeneity, it is noted that their components have great value as aggregates and good mechanical strength, being therefore potential sources for recycled material (Brito Filho, 1999). Pinto (1999) affirms that most of them are composed by recyclable portions and Agopyan (1998) believes that the civil construction sector can absorb almost all of the residuals produced.

Minimising residuals and managing them are the exact points to be under control on the site's environmental management. It is expected that building organisations recognise their stuff being in surplus and the techniques available in order to achieve rationality on the usage of non-renewable sources and other applications for renewable ones.

2.2 Consumption of natural resources

The physical dimensions and the large amount of products produced by contractors, and also the fact that most of the employed materials come from natural resources, makes their consumption another important environmental aspect that must be considered in order to achieve a good environmental performance.

The main environmental impacts that come from the extraction of natural resources concern the exhaustion of the natural resources and the ecological and bio-diversity changes nearby. As it becomes difficult to reduce the volume of materials applied on buildings - except through an efficient waste control - the tendency turns to be selecting the ones that: (a) came from renewable sources; (b) are composed by renewed components; (c) are non-toxic; (d) are extracted under an environmental-concerned methodology; (e) can be recycled, or reused, as a construction material or in some other way; and (f) can be easily monitored during its application, thus avoiding waste.

Even if materials are chosen during the conception phase, contractors should influence the project's specifications. They can join designers during conception or they can propose alternatives during construction, involving new materials and technologies, which can be accepted by the owners.

3 External pressures

Most countries' regulations do not require formal and comprehensive environmental management structures. The same happens in Brazil, where there are a few regulatory demands pushing contractors to move towards sustainability.

Regarding environmental performance, the Brazilian federal law only requires the EIA / RIMA (environmental impact analysis / environmental impact report) and some periodical reports. However, these documents, required by environmental licensing processes, are only applied on those buildings that may significantly modify the environment, such as urban projects of over then 100 hectares and buildings that will be built on natural resource areas, and on heavy construction projects (roads, tunnels, harbours, airports, etc.)[2], where the environmental impacts are quite evident.

It is expected that, in 2003, the CONAMA's resolution #307 could change this scenario. Its proposition aims at putting contractors in charge of their residuals management, which includes characterising, selection, transportation, storage and final disposal, and also to bring to state authorities the responsibility to assure adequate areas to disposal and screening of residuals. That proposition is similar to the one required by PBQP-H[3].

The *Política Nacional de Resíduos Sólidos* is another important instrument to manage residuals. This project is trammelling on the Brazilian Congress and may reinforce the CONAMA's role - although it focuses on solids residual management in general.

Financing programs, mainly using international founds, require more and more an environmental approach of projects. Procurements tend to oblige the presentation of studies concerning project's impacts and the solutions to minimise them.

The results coming from the most important Brazilian's research centres and institutional and private organisations create another external pressure: the known data show how far the contractors' management practices are from the best ones. They are now a reference to contractors in terms of acting efficiently to the environmental issues. The research on recycling and waste reduction matters deserve to be mentioned as the most relevant ones. According to Angulo (2000) the current researches concerning the sustainable development of building construction foster: i) minimisation of waste; ii) improvement on the quality of industrial products; iii) recycling of residuals by re-using construction residuals and other industrial residuals that could also be used in construction; iv) sustainable development focused on project designs; v) increase on the durability of components.

Finally, it is important to mention the existing movement[4] focused on the environmental performance of the contractors' activities and based on environmental assessment methods; they are beginning to influence the Brazilian construction sector. The United States Green Building Council (USGBC) is an example, the LEED™ Green Building Rating System, also adopted in Canada. The Eco-Homes – The Environmental Rating for Homes, from UK, is another example. These assessment methods, as well as similar ones that have been implemented on other countries like Spain, Japan and Austria, are specially based on the Green Building Challenge (GBC) international building environmental assessment tool. They promote the 'building green' philosophy and stimulate the use of recyclable products and environmentally well-fitted projects,

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[2] According to CONAMA resolution # 001/86.

[3] *"Programa Brasileiro da Qualidade e Produtividade do Habitat"*. A federal program that aims to disseminate nation-wide well-succeed civil construction experiments on quality issues. It is a reference oriented to contractors' certification.

[4] Additional data can be found on the United States Green Building Council's home-page; Green Building Resource Guide; Greenbuilder; OIKOS Green Building Source; and other websites. There is also software containing materials data, sources to energy-efficient buildings and tools to assess their environmental performance.

while observing their economic viability and their adaptation to the local community. Another example is the French environmental assessment method, to be applied on educational, commercial and offices buildings and hotels (CSTB, 2002).

4 Contractors' environmental performance

This item presents an overview of two Brazilian general contractors’ behaviour regarding the environmental influences of their on-site activities. The information presented here also consider other contractors' deliberations presented at national and local meetings that have taken place during the author's ongoing research. (The full report of these research can be found at Degani (2003)).

4.1 Awareness

The initiative for environmental approaches should come from contractors' awareness and go through to the anticipation for the new requirements that they expect to impact their practices as a market differential.

A genuine case of contractors' awareness is that of contractor A. They have implemented an environmental management system based on the ISO 14001 requirements, already known by the whole staff, which aims to standardise their actions and guarantee their continued improvement on the minimisation of negative environmental impacts. Nowadays they see their system as an advance and a differential, although they do not apply for an ISO certificate.

In their opinion a certificate will not aggregate significant value, once they already have an excellent image for their clients and society, derived from the quality of their products and services, and mostly by their commitment to fulfil clients' needs.

Contractor A does not have major difficulties to implement their environmental management system, as their routine was already aware of environmental issues. Their management system was already used to hearing from customers and other interested parties. And also, they were familiar with the EIA/RIMA analysis, despite the dimension and location of some of their projects.

However, most contractors are not aware of the environmental issues, until some other factor pushes them. Contractors with an ISO 9001/9002 quality management system and also the level A's at SiQ-C (PBQP-H) seem to be the first ones to become part of the 'awareness team'. That may occur due to some factors: (a) the international standard asks for a complete revision of applied regulatory requirements, revealing the need to approach occupational health, safety and residuals management issues; (b) they already have a formed management system and they know how to achieve and measure their performance through it, and also its benefits; (c) they need to be competitive and focused on costs, market and image; (d) there is real awareness.

Contractor B, an ISO 9002 certified, affirmed that they are trying to fit to the market tendencies and to the legal restrictions that start to emerge. Because of that, many other certified contractors have started, first, to fit their processes and activities to the safe and occupational health issue, and then they intend to gradually introduce environmental practices – so that they will have an integrated management system.

Unlike contractor A, those contractors think that a certified management system aggregates value, by formalising their commitment and ensuring their continued improvement – once they are periodically submitted to external audits.

4.2 Construction waste management

The construction companies that have environmental practices are usually the ones that already have some kind of management system – usually a quality management system. For these Brazilian contractors, residual aware issues are usually solved by controlling their execution processes and their disposal. The execution control aims at reducing loss and waste, and their residual management covers: screening, looking for markets for residuals, and controlling the destination of residuals – which can be done by checking the area where the residuals will be disposed by contracted collectors. The aforementioned solutions are not yet formally documented, nor are they properly implemented on all of those contractors' sites.

The measurement of the volume of residuals generated per activity or service is not yet well known either by the contractors interviewed or by the ones that had been contacted during the research period. Although some of them are already planning to do that and look for buyers or even some firm that could collect them if sorted on sites. Contractor A has mentioned that they started to quantify their residuals in three sites according to their classification as contaminant, non-contaminant recyclable and non-contaminant non-recyclable.

In addition, contractor A keeps a list of their residuals, classified according to the presence of contaminants, and including each disposal practice - which may vary in each Municipality's given support. They mention that they do a residual screening according their own classification, but they only know theoretically where their residuals are disposed by collectors. Contractor A intends to implement selective collection also in their office administration, but doing themselves the screening and the disposal.

Other residual-related practices that start to be seen on sites are: washing of vehicles' tires driven inside sites, to avoid dirtying the public ways; and using their residuals on the site itself on counterfloors, fillings and on the infrastructure of the site itself[5].

4.3 Consumption of natural resources

The evaluation of suppliers is also a routine implemented by all the contractors that have a quality management system. So, the adoption of principles on selecting the sources from which material will be bought could be easily included on their selective and evaluate process, but that has not been done. The cost of the new technologies and materials still counts more than their environmental aspects.

Contractor A's supplier department has started to include environmental requirements such as giving preference to wood coming from reforestation and, where it is possible, trying to substitute some materials.

Apart from that, the main point related to the consumption of natural resources that has to be highlighted is the necessity to involve designers. Most impacts observed during a building's whole lifecycle are defined in the design phase, but so far the awareness of architectural designers is limited to minimising or even compensating suppression of vegetation. Despite the fact that installation designers have already started to consider, in their projects, the necessity to minimise water and energy consumption and some aspects of maintenance and durability are still present.

[5] Re-using of residual at some sites is cited in Grigoli (2001).

4.4 Other environmental practices

We can also mention other environmental practices - although observed at only a few contractors – such as: (a) training to minimise water and energy waste – although much more in order to reduce costs and in attendance of federal saving programs than due to proper environmental concern; (b) monitoring vehicle gas emissions during delivery of products; (c) monitoring deliveries to avoid materials damage and spilling on public ways; (d) adoption of some features to minimise particulate emissions, such as sprinkling the outdoor storage of materials or sprinkling the dry soil; (e) conducting noise measurements and establishing time schedules through agreements with the neighbourhood; (f) having efficient means of communication with the community and the neighbourhood; (g) controlling the storage of materials in order to avoid loss and dispersion of particles; (h) maintaining the site in good hygiene and safety conditions; (i) avoiding excessive suppression of vegetation.

More specifically the contractor A has: (a) procedures to identify the impact of the project on the environment during the construction phase (this practice is conducted for each individual project and performed by that project's specified technical team); (b) periodic reports that illustrate the environmental aspects and solutions implemented on the sites; (c) a routine to measure the significant environmental aspects on plants.

Still concerning contractor A, which has an environmental management system (EMS) implemented, there are some relevant facts to mention regarding its implementation: (a) there were hired consultants to guide the implementation and they were responsible to identify contractor A's environmental aspects and applicable regulatory requirements; (b) there was no need to hire additional personnel and neither to create a specific sector; all of the new practices were attributed to the existent functions; (c) no additional costs were necessary to implement their EMS, the only relevant expense was with consultants' assistance; (d) the first EMS presentation to suppliers was done by the directors themselves .

Concerning responsibilities, still on contractor A's system: (a) monitoring the EMS on sites must be done by the safety engineer or technician; (b) all the training and audits are made under the supervision of human resources department; (c) the technical teams of each site are responsible to issue a monthly environmental report; (d) for each new project, the assigned technical team has the responsibility to identify the significant environmental aspects and impacts.

4.5 Difficulties

Brazilian contractors have pointed out some difficulties concerning the implementation of positive environmental actions. Considering residuals, they argue that selecting their residuals on sites is not easy because the supply chain is not well developed in Brazil: is difficult to find someone who could collect, screen, store, recycle and then commercialise recycled products. Most Municipalities do not subsidise those activities and there is no place for residuals storage on sites.

Taking care and being responsible for the final destination of residuals is also not easily achieved, since there are just a few reliable residual removers that actually dispose them on licensed areas. Even the Municipalities could not offer regular disposable areas and the existent ones are usually far from collection points.

Another difficulty is to measure the volume of residuals generated by each service developed on site, in order to commit subcontractors. That knowledge could lead to the weak points where the preventive actions should be applied, in order to reduce materials waste.

Concerning the consumption of natural resources, its reduction is related to the substitution of materials and techniques used on-site. The difficulties arise from the fact that selecting materials and techniques is conditioned to the project and to whom is going to pay for a possible additional cost.

Another difficulty pointed out as something that needs improvement is service suppliers' culture. They do not yet easily accept new practices. According to contractor B, the hardest target to achieve may be making their service suppliers' personnel aware with environmental issues.

It seems also an obstacle the poor knowledge of the necessary expenses that an EMS requires.

4.6 Performance of contractors' existing management systems

Contractors who own effective management systems already have some records showing that it is necessary to monitor their environmental aspects and also customers' and neighbourhood demands. Contractor B has recorded neighbourhood complaints related to noise and vibration, and some other information related to building environmental performance - provided in their post-occupation assessments.

Some contractors already mention environmental preoccupations on their policies, although they do not yet include them on their established objectives and targets, nor on their specific programmes.

Regarding training, it is already a part of some contractors’ routine. They are also planning to include the environmental education on their planning scheme.

Regarding communication, at the investigated contractors, the information flows through their records: nonconformities; improvement evidences; feedback provided by clients and users; and other. However, their dissemination to all of the staff involved is not yet assured, being sometimes restricted to top management reviews. In addition, their external communication is not standardised, except for their post-occupation assistance.

The information related to environmental aspects does not appear on the contractor's systems records. They are not yet included on their monitoring and inspection checking-list.

A deficiency noted on some Brazilian general contractors management systems, which may affect the environment, is the absence of documented procedures related to the identification of potential emergency situations, as fires or collapsing for example. Another deficiency found on sites is that these contractors have good storage identification signs but do not have features to prevent leaking and spilling.

The interviewed contractors have effective operation of their management systems and have started working on their revision. While filling the requirements of the 2000 version of ISO 9001, they are also achieving some ISO 14001 requirements.

The necessity to minimise environmental effects of contractor activities is evidenced when contractors try to guarantee conformity to applicable regulatory demands. Because of that, some contractors first add safety and occupational health procedures – according to the Brazilian rule concerning safety and occupational health on sites, NR 18, and the OHSAS 18001 specification – thus showing the belief on integrated management systems. Relating to CONAMA # 307 resolution and to the *Política*

Nacional de Resíduos Sólidos, they know them, but they are still waiting for their publication and their impacts on the supply chain and the competitors' actions.

It is also important to mention that there are still many certified contractors who have broken their policies' commitment or that do not know the essence of a management system to enhance their activities and results. For those, introducing environmental practices may work partially on some sites, but not in a standardised and continued fashion, as it is desired.

5 Conclusions

In Brazil, the most relevant environmental aspects, as a consequence of contractors' activities on sites, are the large volume of solid residuals disposed on urban environment and the large consumption of natural resources. Some Brazilian contractors have shown concern on these issues and have made some advances to reduce their interference. However, most of them are not aware of this and will remain as that until an external factor pushes them to change.

ISO 9001/9002 certified contractors seem to be the first ones to become part of the 'awareness team'. For those Brazilian contractors, the residue issue is usually solved by controlling the execution processes and the residual disposal, although their environmental practices are not yet formally documented, nor properly implemented on all of those contractors' sites.

Also considering residuals, Brazilian contractors complain that the supply chain is not able to take care of site residuals. Most Brazilian Municipalities do not subsidise the related activities. Another difficulty presented by Brazilian contractors is taking care and being responsible for the final destination of their residuals, since there are only a few reliable residuals removers that actually dispose on the licensed areas – even there are few regular disposable areas offered and they are usually far from the collect points.

Concerning the consumption of natural resources, there are a few Brazilian contractors that are trying to substitute materials and techniques. The difficulties arise from the fact that their selection is conditioned to the project and to who is going to pay for a possible additional cost.

Making their service suppliers' personnel aware of environmental issues is also a target that is hard to achieve, according to Brazilian contractors, and also, the ignorance of the necessary expenses that an EMS requires.

The description of Brazilian contractors' behaviour presented in this article leads to the following classification of contractors:

1. aware contractors that have already implemented some pro-environment practices, but still have difficulties due to the lack of support by Municipality and designers;
2. contractors that have an efficient quality management system implemented, certified or not, that have seen the feasibility to include environmental practices in their existent systems, and also their worthy market contribution; however they have begun by responding to ISO 9001:2000 requirements and to safety and occupational health issues, and they later intend to focus on environmental matters;
3. contractors that are waiting for the new environmental legal requirements to come into force, and to be rigidly supervised, before they start to act;

4. contractors, certified or not, that have broken their policies' commitment or that do not know the essence of a management system in order to enhance their activities and results; for those, introducing environmental practices may work partially on some sites but not in a standardised or continual fashion as it is desired.

It is expected that the legal requirements oriented to Municipalities' commitment, and also the suppliers and designers' environmental awareness, could provide a better scenario to stimulate contractors' action towards sustainability.

Contractors, who have effective operation of their management systems and have benefited from them, are already structured to add environmentally good practices. The tendency seems to be integrating the environmental practices into the existent ones.

Because sustainable development and attitudes aimed at minimising environmental impacts and maximising environmental performance are now a tendency and soon will become a demand by stakeholders, contractors should anticipate them.

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Learning capability in construction projects: from the learning organisation to the learning project

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Abstract

Effective learning is a crucial element in any management system. In the construction industry, the lack of feedback and knowledge transfer is mentioned as one of the core challenges for delivering sustainable buildings. Another challenge is developing individuals working in the projects and transfering knowledge between projects. It is generally recognised that learning take place in construction projects, nevertheless most research examines the concept of learning either from a company perspective, i.e. how learning can be integrated in the company's management system, or by focusing on learning within specific professions. This paper aims at filling a gap in the organisational learning literature by introducing the concept of learning capability in construction projects. The influence of contract form, organisation, culture, knowledge, leadership etc is discussed, including how it is integrated in the project management system. The paper is based on a literature review of the concepts of learning theories and characteristics of construction projects. It argues that more research is needed to identify how construction projects should be organised and managed to increase the individual learning as well as the organisational learning.

Keywords

Construction project, learning capability, organisational boundaries, organisational learning

1 Introduction

Construction industry has the image of being an old-fashioned, slowly changing industry that cherishes outdated methods and working styles. The fear of possible consequences strongly limits the experimentation with new materials, contract forms and working styles. There is a clear opinion that the construction industry has to overcome outdated traditions by speeding up and improving the learning processes.

Internal and external environmental factors influencing construction projects are dynamically changing and unstable. Effects of changes during the construction project time are highly unpredictable and can have significant effects on the organisation as well as on the project outcome (McGill and Slocum, 1993; Kululanga *et al.*, 1999; Love *et al.*, 2002,). Additionally, outdated working and communication styles as well as slow adoption to new medias and working tools strengthen the perception of an old-fashioned and unattractive industry. This leads to difficulties in attracting qualified and highly motivated employees (Gomar *et al.*, 2002).

The project structure, with clearly separated phases, tight timeframes and high fragmentation characterise construction projects. These characteristics create organisational boundaries, limiting the flow of information and heavily influence the communication, which in turn leads to a reinvention of already known solutions. Errors, rework, inadequate methods and traditional but not value-adding activities lead to high avoidable cost and low profit margins. Overcoming those roadblocks by improving knowledge, cooperation and communication can offer excellent opportunities to increase the attractiveness and profitability of the industry.

This paper introduces the concept of organisational learning capability in order to understand existing and absent learning processes in construction projects. The aim is to provide an overview of organisational learning in construction projects and to identify relevant areas for further research.

2 Theories of learning

In the past few years the literature about learning has grown rapidly as an answer to challenges caused by an always faster changing environment. According to Yeung *et al.* (1999, p21) the roots of “learning organisations” can be followed back to the early 1900s to Frederick Taylor, who argued that when management standards were articulated and measured, it is possible to transfer this learning to other employees and improve the organisations efficiency. More recently, Argyris and Schön (1996, p180) divided the literature on organisational learning into two categories: the principally sceptical scholarly literature of *Organisational Learning* and the practice-oriented, prescriptive literature of the *Learning Organisation*.

2.1 Organisational learning

Argyris and Schön (1996, p188) argue that “the literature on organisational learning is intentionally distant from practice, nonprescriptive, and value-neutral”. Cook and Yanow (1993) describe organisational learning as a category of activity that can only be conducted by a group and not by an individual: “In this respect, organisational learning, as we use the term, refers to the capacity of an organisation to learn how to do what it does, where what it learns is possessed not by individual members of the organisation but by the aggregate itself. That is when a group acquires the know-how associated with its ability to carry out its collective activities, that constitutes organisational learning” (Cook and Yanow, 1993, p438). Yeung *et al.* (1999, p28) consider learning to be organisational when ideas and knowledge generated by individuals within the organisation are shared across organisational boundaries of space, time and hierarchy. These kinds of organisational boundaries characterise construction.

2.2 Learning organisation

The learning organisation approach is more practical and action-orientated. It can be considered as a counterpart to the more theoretical approach of organisational learning. That being said, the learning organisation literature is not devoid of theory; it draws very heavily from ideas developed within organisational learning but it is selective on the grounds of utility (Esterby-Smith, 1999). Although this literature takes many forms, its underlying conception of a central idea is broadly shared. This ideal includes notions of organisational adaptability, flexibility, avoidance of stability traps, propensity to experiment, readiness to rethink means and ends, inquiry-orientation, realisation of human potential for learning in the service of organisational purposes, and creation of organisational settings as contexts for human development. Senge (1990) defines a learning organisation as an organisation that is continually expanding its capacity to create its future. For such an organisation it is not enough merely to survive.

2.3 Organisational learning capability

The term capability can be followed back to the early 1990's where it was mainly used as a general concept for resources and skills or competencies (Teece *et al.* 1990; Leonard-Barton 1992). Organisational learning capability can be achieved, when an organisation learns from its experiences and has the ability to pass these lessons across different kinds of boundaries (Ashkenas *et al.* 1995). Yeung *et al.* (1999) narrows this definition by adding the necessity of impact: "An organisations fundamental learning capability represents its capacity to generate and generalise ideas with impact (change) across multiple organisational boundaries (learning) through specific management initiatives and practices (capability)" (Yeung *et al.* 1999, p59). They contend that learning capability is based on three building blocks: (1) Generation of ideas, (2) generalisation of ideas, and (3) identification of "learning disabilities".

In addition, Yeung *et al.* (1999) argue that the base for organisational learning capability is strongly formed by the overall organisational culture and commitment of leadership. Further on competence, consequence, governance and capacity for change directly influence it. Competence ensures that the individual, the team and the organisation have the right competencies to learn, by right staffing, training and development of the employees. In addition, consequences have to encourage learning on all levels, while governance takes concern about the organisational structures. Capacity for change on the other hand estimates to which extent work processes encourage learning (Yeung *et al.*, 1999). DiBella and Nevis (1996) state that there is not one way to establish organisational learning capability; rather the learning style has to fit its product, service and environment.

2.4 Forms of learning

During the 1970s Argyris and Schön established their theory about single and double loop learning. They define single loop learning as "instrumental learning that changes strategies of action or assumptions underlying strategies in ways that leave the values of a theory of action unchanged" (Agyris and Schön, 1996, p20). They mean that double loop learning is superior to single loop learning and argue that hardly any organisation achieves the statues of double loop learning.

Organisational learning can be achieved by adapting concepts like dialog, system thinking or reflection. "The dialog is a structured method for intervention into ongoing workgroups which requires members to allow space for each other to speak, to avoid evaluating the comments of each other, and to be willing to speak out on their own views" (Isaacs, 1993). According to Senge (1990) system thinking integrates the disciplines of personal mastery, mental models, shared vision, and team learning into one unit is essential for learning organisations. Reflection is a tool that Schön (1999) sees as necessary: "It consists in on-the spot surfacing, criticizing, restructuring, and testing of intuitive understandings of experienced phenomena; often it takes the form of a reflective conversation with the situation" (Schön 1999, p241).

Although the theory about learning has some shortcomings, like the missing of a general accepted concept (Fiol and Lyles, 1985) or the strong interest in designing one ultimate concept that enables learning (Senge, 1990), its most substantial benefit lies in the focus on the individual within its organisational context. Organisational learning capability is of high relevance for workforce intensive organisations such as the construction industry.

3 Learning in construction projects

The construction industry is, as all other industries, strongly shaped by its environment. Contract forms and process flows develop and change according to environmental demands and needs. People in the industry work in shorter projects with increased number of actors involved. Existing organisational boundaries are growing stronger and new boundaries arise.

3.1 The contract forms

Projects are organised in different contract forms. Total construction contract, general construction contract and shared construction contract as well as combinations of the three basic forms are widely used. The contract form is chosen according to the specific needs, because it strongly influences communication and decision-making. For example, there are normally no informal communication between designers and contractors in general construction contracts. Carlsson and Josephson (2001) indicate further, based on four case studies, that individuals learn more in total construction projects due to enhanced feedback and more time for reflection.

In the last few years, new contract forms have emerged, aiming to adapt to new customer demands. Examples of new contract forms are Private-Public Partnership and partnering: "A Public-Private Partnership is a partnership between public sector and private sector investors and businesses, for the purpose of fully undertaking the tasks of planning, designing, financing, constructing and/or operating a service otherwise provided by the state" (Leiringer, 2001). Partnering is a contract between two or more organisations to achieve a shared goal by using each other's resources in an optimal way. Kadefors (2002) regards partnering as a means to overcome contractual boundaries and facilitate team working across such boundaries. Relation building, a shared goal, a system for problem and conflict solving and a system for following up and measuring progress are seen as the fundamental components for partnering. Therefore, trust is a major factor for learning over organisational boundaries (e.g. client-contractor). Kadefors (2002) argues that the contract form and the lowest price winning results in a behaviour where any participant in the process assumes to be cheated. Partnering and long-term agreements are seen as a solution to overcome the defensive behaviour of the participants. There are several elements in these new forms of contracts that enable for enhanced learning. Empirical studies indicate that partnering increases learning, probably due to improved communication over organisational boundaries (Barlow and Jashapara, 1998; Josephson and Lindahl, 2002).

3.2 The construction process – communication and information

The construction process is traditionally divided into four principal phases: Idea and evaluation, design, production and utilisation. The boundaries between these phases are of different strength depending on the contract form. The phases follow one another, which means that almost new organisations are created for every new phase. Handing over the product from one phase to the next involves loss of knowledge as well as of information and skills (Spatz, 2000).

Communication is one of the most powerful enablers for sharing information for generalising ideas. Collectively, formal and informal processes for communicating ideas can be useful tools for sharing information across boundaries as long as they work toward the same business goal (Yeung *et al.*, 1999).

Successful knowledge transfer is based on an understanding of one another; therefore a shared language is required in order to enable for effective communication. However, similar to the difficulties that arise when architects, structural engineers, and contractors are unable to communicate because of a lack of shared vocabulary, organisations cannot develop long-term plans when members are working from different definition bases. Reducing uncertainty and miscommunication require a common understanding and interpretation of foundational concepts (Chinowsky and Meredith, 2000).

Newcombe (1996) argues that communication, as a base for empowerment is most likely to be improved by enhanced relationships among team members, while formal techniques play a less important role. Huemer and Östergren (2000) argue that there exist only a few systematic approaches for sharing experience and even those that have been developed are rarely used. Another factor limiting the feedback process is time. Scott and Harris (1998) explain: “The majority of the learning appears to be unstructured, involving the collection of information, but failing to put it in good use. The corporate attitude seems to be that information gathering will only take place when there is time and money to allow it” (Scott and Harris, 1998, p124). Smaller companies may, Bang and Clausen (2001) argues, face even more challenges: “Learning mechanisms in the firms in terms if institutionalised (formalised) procedures for systematic knowledge accumulation are relatively uncommon. In small firms only the owner is normally engaged in daily, continuous collection of experiences and lessons learned” (Bang and Clausen, 2001, p205).

Sharp boarders and the lack of knowledge brokers are other problems limiting information transfer (Josephson and Lindahl, 2002; Spatz, 2000). Spatz (2000) argues for a need of cross-organisational and cross-functional project teams in order to reduce the loss of information when the product is handed over to the next phase: “When individuals from earlier phases are involved in later phases, skills are transferred, learning and knowledge are shared, and projects benefit by having committed, interested stakeholders contributing to project quality and improvement downstream. Team environments encourage and support high performance collaboration” (Spatz, 2000, pp100).

3.3 The construction worker

The construction companies are facing problems with recruiting new personnel, especially blue-collar workers. Reasons for this are the poor image of the industry and the lack of opportunities for training and career growth. Short employment durations and frequent seasonal layoffs, but also the sensitivity to economic fluctuations lead to high fluctuation of experienced workers in construction (BRT, 1997; Liska, 1998).

Among different concepts that may be of help when dealing with this problem, Gomar *et al*. (2000) addresses *multiskilling* as a method to overcome the problem of frequent lay off and the thereby caused knowledge loss. Multiskilling also reduces the number of organisational boarders.

Overcoming traditional hierarchical structures and motivating subcontractors and workers through empowerment of the workforce as another approach is discussed by Newcombe (1996). He argues that empowering different parties can help to focus the whole organisation on one goal and in this way improve the financial outcome, due to a win-win situation, as well as the personal satisfaction. To successfully adhere to an empowerment strategy, self-confident leaders are needed and the workforce has to be capable to handle the higher responsibility.

In addition, inter-organisational teamwork can positively influence the project outcome as well as the members' commitment and therefore it can be a method to keep eager workforce. "The potential benefits of using inter-organisational teamwork effectively in public design and build projects or total construction projects are not limited to the project itself. Project participants may gain a higher level of job satisfaction as well. Perhaps more important is that a positive relationship between job satisfaction and project performance is found" (Chan *et al*., 2001, p39). However the positive effects of teamwork are very likely to be cancelled by a rough climate that makes it impossible for team members to admit mistakes: "It is also questionable whether the teams are actually characterised by high tolerance. To facilitate learning and exchanges of experiences, the climate should be such that individuals are not afraid to make mistakes" (Anheim, 2002, p159).

However, it can be questioned if learning always creates positive effects in developing individual and organisational competencies. It may also strengthen wrong or inefficient routines. Gherardi (2000) examines a safety case where positive as well as negative learning occurred. New employees are often copying safety behaviour of established co-workers even in cases where they know their behaviour is risky. On the other hand, positive behaviour is taken over by organisations but their filtration time is much longer.

4 From the learning organisation to the learning project?

Most literature about organisational learning theory focuses on the organisation as a construct that is more or less stable over time. In most cases the focus is on a company while in other cases on a profession. However, construction projects differ from stable organisation in several aspects, which influence the learning capability.

4.1 Characteristics for project organisations

The timeframe for projects is normally short, while it is relatively long for companies and professions (Table 1). The turnover of personnel is high during the project process. In construction a new project normally means a new location for the final product. The fragmentation of the process, i.e. the number of activities and experts involved, is high. The information structure is complex. Finally, the project members work at many different places at a specific time, e.g. during design. Therefore, it is often argued that it is more complex to establish routines in project organisations than in companies and for professions. A main reason is of course that the project members come from many different companies and belong to many different professions. Following that, learning capability in projects involves more aspects than learning capability in companies or in professions.

Table 1: Principle characteristics for project organisations (temporary organisations), companies (permanent organisations) and professions.

Factor	*Temporary org.*	*Permanent org.*	*Profession*
Timeframe	short	long	long
Turnover of personnel	high	low	periodic
Location of organisation	varying	fixed	fixed/varying
Fragmentation	high	low/high	low
Information infrastructure	complex	simple/complex	simple
Number of workplaces for the members at a specific moment	many	few/many	many

4.2 Organisational boundaries to overcome

We have seen that construction projects involve several organisational interfaces or organisational boundaries related to time, hierarchy, location and culture. These boundaries hinder design and production of sustainable buildings as well as establishing effective learning processes. For example, Josephson and Hammarlund (1999) found that the underlying causes of most errors occurring during production were related to four types of instability in project organisations: new vertical relations (e.g. between client and designer), new horizontal relations (e.g. between two sub-contractors), project members joining the project organisation too late, key persons are exchanged. These instabilities create new boundaries or strengthen existing ones, which increase knowledge losses and limit the learning.

Organisational boundaries related to time involve that sub-organisations and individuals not meet each other. Of that reason, knowledge and experience cannot be exchanged between project members. For example, thoughts not included in drawings cannot be explained to the contractors, information on critical activities cannot be transferred sufficiently and feedback cannot be given. Project members leaving the project early can cause a loss of valuable information whereas those coming late may not get a more elaborated understanding of earlier decisions as well as extra time for becoming familiar with the project is often needed.

Boundaries related to location also involve that sub-organisations and individuals not meet each other. A typical example is that designers work at their home offices and only meet now and then. However, in few larger projects special design offices have been organised. Another example is that the contractor has some managers on site and others at the main office. This splitting of location leads to difficulties in collecting, storing and distributing relevant information in a way that is accessible by most participants and can therefore limit the learning capability. To overcome this difficulty advanced information systems that are easily accessible from any location can be a solution.

Hierarchical boundaries imply that individuals at different organisational levels do not exchange sufficient knowledge and information. A typical example is that the contractors’ project manager does not understand the site managers’ need of support or that the site manager doesn’t ask for support.

There are also culture related boundaries between professions because of their different education and roles, for example between architects and contractors. A common concern is that professions tend to generalise the behaviour of other professions. For example, all architects are handled in the same way regardless their expertise, experiences and personality. In this way a professional behaviour is created that may hinder learning.

This fragmentation in different disciplines and the number of boarders make learning more complex but also more interesting to improve. It is a general opinion that the information flow through the construction process is underdeveloped and that feedback loops are almost non-existing. One improvement approach is to reduce or even completely overcome the boundaries by new organisation structures or improved communication between the different project members.

5 Conclusion

This paper is aimed at giving an overview of existing organisational learning theories with a focus on organisational learning capability and their appliance on research regarding construction projects organisations. It shows that great emphasis is laid on theoretical discussions and advices about how learning cultures are likely to appear and how they can be achieved by using specific techniques. On the other hand, much less research is paying attention on empirical studies about learning occurring in reality: “Research has concentrated on describing learning organisations and on individual customised implementations of organisational learning concepts and tools in a variety of organisational types” (Ford *et al*., 2000).

A concentration on single aspects of organisational learning capability or tools is noticeable, whereas a comprehensive view about the implications on the single person or on the organisation is fairly neglected. A viewpoint within or about one company is common, although it is against the nature of construction projects, which are characterised by cooperation of several companies and the involvement of numerous specialists. From a managerial view exists an interest to see the impact of investments in training or new communication infrastructure and their usefulness.

For achieving a comprehensive picture about how the learning situation in building projects really is, how existing theories and methods are applied, broader empirical studies are necessary in addition a generalisation of results found by applying case studies can be performed in this way. Another important factor is to widen the perspective by adding interacting partners in the learning process. Huemer and Östergren (2000) identify a general lack of systematic empirical studies, whereas numerous normative concepts, about what organisational learning should be, exist.

The research indicates that most hinder for learning are related to existing organisational boundaries. These boundaries may exist because the project organisation includes many companies and many professions. However, there seems to be no empirical studies aiming at identifying and analysing these boundaries in a broader sense. Such study should give a good overview of the learning capability in construction projects. The industry should get information on how to organise their projects for increased learning. Further, it should guide the creation of more focused studies on learning capability.

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Learn with the Accidents in the Building Construction

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Abstract

The study was based on the analysis of Safety's Plans in Construction and in the statistics of construction work accidents in Portugal. The collected data was obtained from several sources including insurance companies, official published statistics, building construction companies, hospitals, police, other publications and mainly from professional associations. The analysis of Safety Plans in Construction was based on the supplied elements, having as final goal to obtain a comparison, through the compared statistical analysis of the accident indexes, among the number of occupational accidents in the Construction. The objective was to obtain a cause effect relation, to know which kind of accidents are most frequent, the most common mistakes, the type of injuries that occur from the accidents and their seriousness. This analysis allowed, in terms of objectives, to detect the most common mistakes that imply the possible occurrence of construction work accidents and therefore aiming at the adjustment of more effective preventive measures.

Keywords

Construction; safety plan; risk analysis; implementation; accidents; work site

1 Introduction

This research makes the analysis of the implementation of construction safety plans, of inspection records and of prevention of safety irregularities during the construction of a shopping centre. The data recovered and analysed was obtained from several sources like statistics from official organizations, building construction companies, professional associations and related publications. This analysis intends to verify which are the most common safety irregularities and respective duration trying to lead to the proposal of preventive measures to minimize the probability of occurrence of accidents.

The final objective is to know if the implementation of the construction safety plans is applied with the proper criteria and to determine which are the most common mistakes committed during the execution and what are the respective corrective measures. The irregularities found in the shopping centre were listed and divided in three groups being the first composed by those already corrected, the second by those in the process of being rectified and the third by those detected waiting for the corrective measure.

For a better understanding of the distribution of these types of irregularities it was created a bar chart where each of the errors detected was represented by a bar indicating the date when it was identified and, when applicable, the date it was rectified. The observation started in December 2001 and different colour schemes were defined for each different type of error and also for the various types of the degree of gravity of the irregularity.

2 Procedures, inspection records and prevention

The execution of a building comprises a set of activities where each one has different levels of risk that have to be quantified and minimized. To analyse the existent risks in the execution of each one of the tasks in a clear and brief mode it was necessary to use a complete set of inspection records and of adopted corrective measures. The records are classified in three types like inspection procedures, inspection records and corrective actions. In table 1 it is presented an example of a type of inspection procedure and prevention accompanied by the respective detailed description of the related construction task.

Table 1- Type of inspection procedure and prevention

Inspection procedures and prevention				N.º	P.
Owner of the work			Representative		
Work					
Designer			Coord. Safety (design)		
Engineer			Coord. Safety (execution)		
Construction task / Element construction code					
Checking/tasks	Risks	Reference documents	Prevention Actions	Inspection frequency	

After the use of the inspection records to control the analysis of the scheduled construction tasks a record is produced in an adequate model and an example is presented in table 2. With the production of these records the goal is to draw the attention of the contractor to the responsibility of the implementation of the respective corrective measures.

Table 2 - Model of a record of Inspection and Prevention

RECORD OF INSPECTION AND PREVENTION		N.º	P.
Owner	Representative		
Work			
Contractor			
Construction task / Element of construction code			
Place/Activity			
Verification / Activity	I control		
	Contractor: Date: Signed:	Contractor: Date: Signed:	
	Supervision: Date: Signed:	Supervision: Date: Signed:	

2.1 Record of irregularities and of corrective measures

The errors appear whenever, for certain tasks, the risk of an accident exists. This record is made as a follow-up track of the irregularity instead of the inspection record and prevention. When this situation occurs, according to the contract made between the owner and the contractor, there is a withholding of 0,5% of the monthly invoice per each of the non-rectified irregularity. This withholding is maintained until the contractor corrects the error. The record of irregularities aims at improving the construction safety level and, therefore, deserves a thorough analysis allowing an insight of the effects of the errors recording and of the respective corrective measures. Another important benefit is the identification of errors that were not identified in the original construction safety plan. An example of this type of recording is in table 3.

Table 3 - Record of irregularity and of preventive action

Record of Irregularity and of Preventive Action		N.º	P.
Owner	Representative		
Work			
Contractor:			
Construction task / Element of construction code			
D Description of the irregularity			
Location:			
Documents of Reference:			
Contractor: ____ / _____ / _____	Supervision: ____ / _____ / _____		
Description of the Preventive Actions:			
To correct until: ____ / _____ / _____			
Contractor: ____ / _____ / _____	Supervision: ____ / _____ / _____		
Verification of the Preventive Measures:			
Contractor: ____ / _____ / ____	Supervision: ____ / _____ / _____		
Coordinator of safety and health: ___/___/____	Manager: ____ / _____ / _____		

3 Most frequent anomalies

The analysis of the anomalies in the construction safety implementation since the beginning of the research in 6 December 2001 allowed predicting the probability of occurrence of each one based on the records and on the frequency of similar construction works. The compilation of these anomalies is presented and resumed in table 4.

Table 4 - Most frequent anomalies

Description	N.º of Times
Incomplete work platforms	16
Access stairways without conditions of safety	15
Lack of body rails	15
Lifting loads with the crane with the inadequate devices to the type of loads	8
Workers without using the equipment of individual protection	7
Inadequate auxiliary means of lifting	5
Movement of suspended loads in incorrect form	5
Lack of signals on site	5
Lack of sound signals behind in the shipyard equipments	7
Steel bars without cap protection	4
Incorrect storage of materials	4
Access to the crane without conditions of safety	4
Threads and electric cables risking cuts and crush	4
Cabin of distribution of electrical energy unprotected	4
Incomplete scaffolds	3
Incorrect use of the equipment of removal of loads	3
Lack of inspection procedures and prevention of the constructive methods	3
Bedrooms without hygienic conditions	2
Disarranged shipyard	2
Workers' passage in areas where there is the danger of land slides	2
Lack of first aid nurse nomination and delivery of related documents	2

4 Correction of anomalies

Analysing the anomalies of longer duration, some conclusions can be reached like the length of time needed for the application of the preventive measures or like the rate of occurrence of the following anomalies. Figure 1 shows that the anomalies of longer duration that have larger meaning are the access stairways without safety measures with a rate of 30%, the inadequate work platforms with 21%, followed by the inadequate displacement of materials with an occurrence of 14%.

The analysis of figure 2 indicates that the duration of inadequate access stairs, of improper work platforms, of lack of inspection records and of lack of records of site equipment is about three hundred days. Other anomalies, like improper transportation of materials, lack of control of site access and risk of landslides, are within an interval of fifty to seventy days.

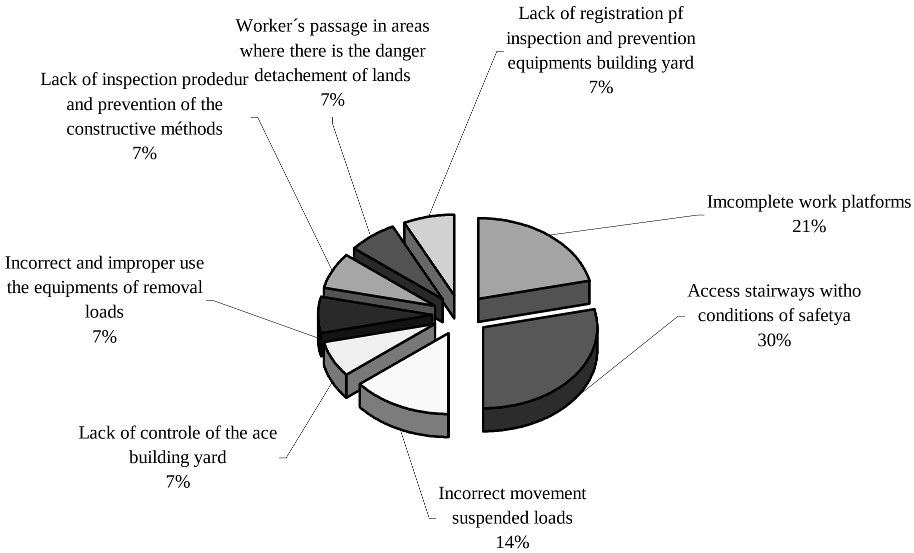

Figure 1 - Percentage of anomalies detected

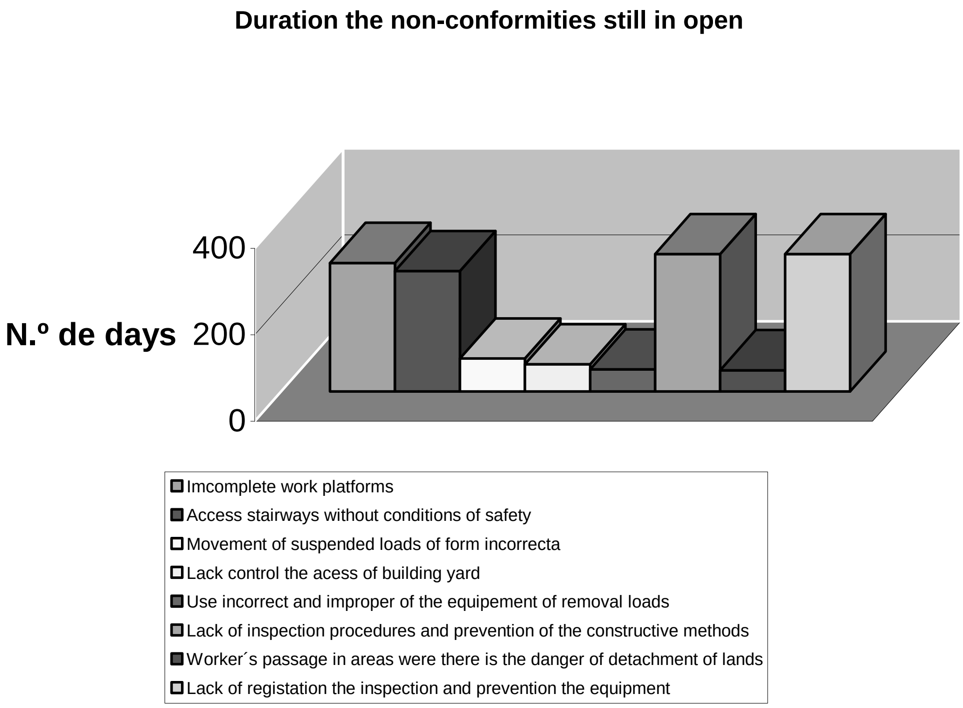

Figure 2- Number of days of anomalies

A third analysis made was the relative distribution of anomalies with longer duration. Inadequate access stairways presented a rate of 19%, followed by the lack of proper documentation about subcontractors with 18% and the others presented an average of 9%.

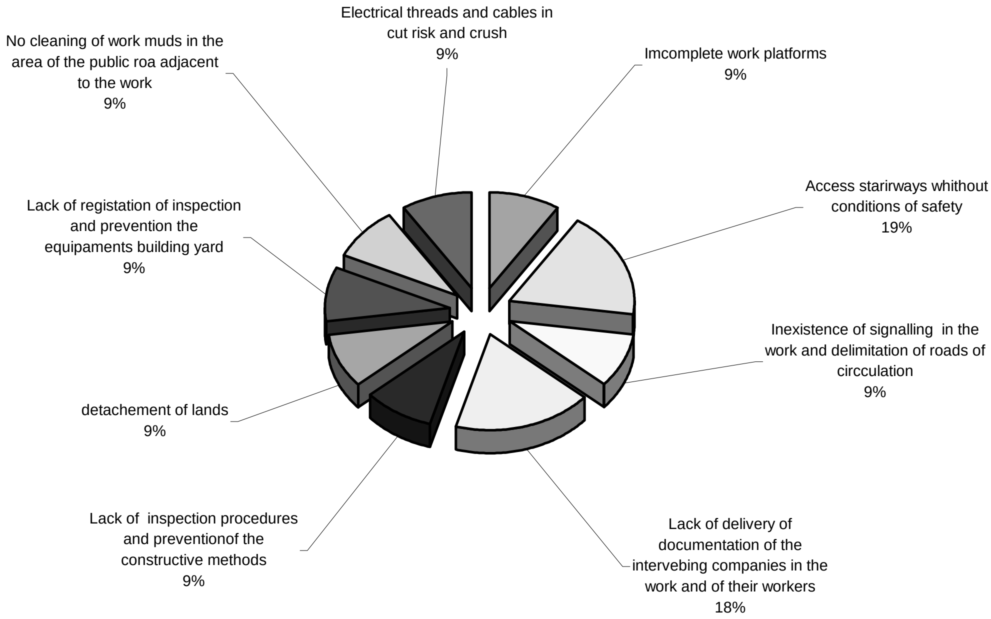

Figure 3- Relative percentage of anomalies with longer duration

In figure 4 the anomalies that were detected were corrected after a considerable period that varies between nine and eleven months. The longer are the lack of inspection procedures, the lack of documents from subcontractors, the incomplete work platforms, the stairways without safety conditions and the non-existence of road and circulation signals.

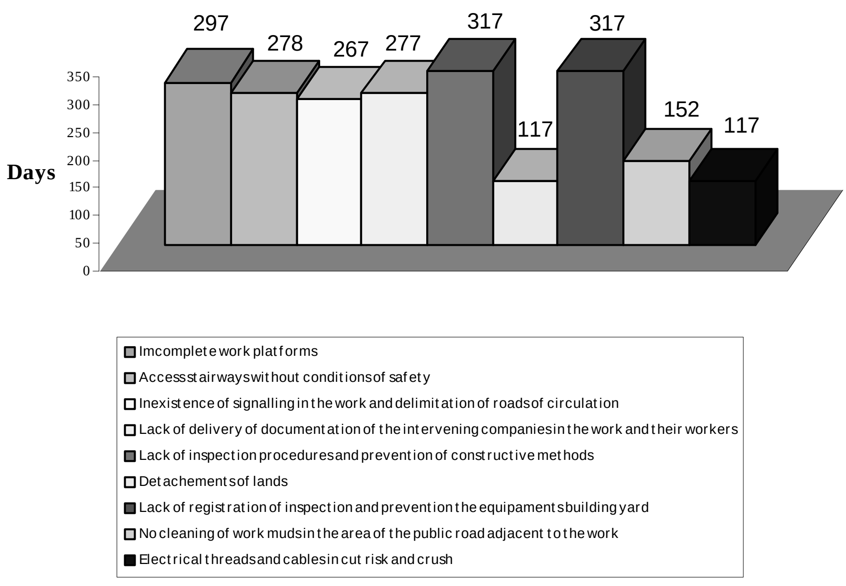

Figure 4- Number of days of uncorrected anomalies

5 Difficulties in the implementation of safety plan

Since the publication of the construction safety legislation in 1995 other related legislation was produced. The main obstacle in implementing the construction safety plans is that the contractor and the owner, in general, perceive safety as a cost and not as a benefit. It is shown through research works, that safety in construction reduces the overall costs as shown in table 5.

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Table 5- Relationship of expected values of costs of construction accidents

Point of view	Economical Advantages
Construction company	3
Insurance company	21
Social	5

Analysing the costs of expected accidents presented in table 5 one concludes that the construction company would save about three times what it would spend in the implementation of the safety plan if an accident of average seriousness occurs. The insurance is saving more than twenty one times the insurance premium if no accident occurs and in social terms the savings is about five times. It is worth investing in effective prevention when looking at costs that are easily accountable since these values do not consider other collateral damages that can not be quantified in economic terms.

Other obstacles to effective safety implementation are the lack of strategy towards safety in construction companies, absence of adequate worker training, lack of proper culture of safety and inclusion of safety as a traditional item in the budget.

6 General conclusions

After having analysed the anomalies one of the conclusions is that it takes time to correct the anomalies even with the withholding of the respective fines. Another aspect is that the correction of some anomalies depends of the rectification of others. A third main conclusion is that the prediction of anomalies through the analysis of previous records is an efficient tool to draw the attention to the greater risks of possible accidents. National statistics of the construction sector show that a large number of fatal accidents result from falls. These values are represented in figure 5 and presents values for erection of scaffolding, roof work, floor gap, floor opening, stairs, scaffolds/platforms and others.

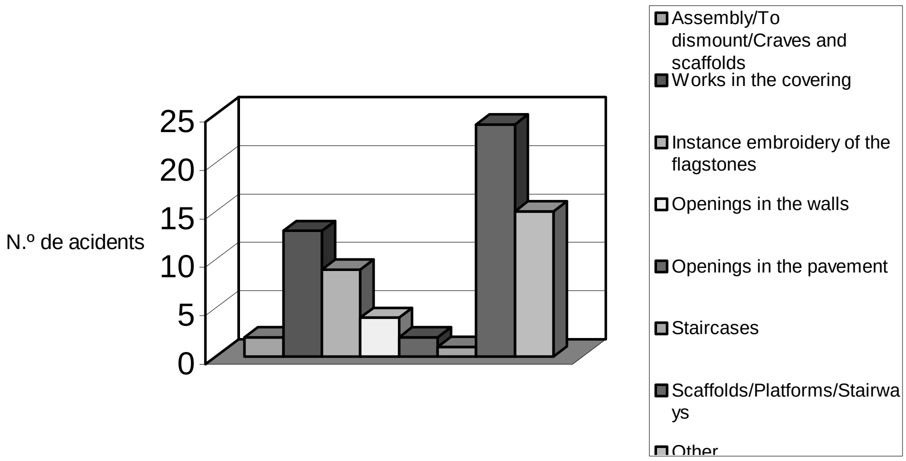

Figure 5- Fatal accidents due to falls in 2000

In the two hundred and twenty anomalies that were analysed other common errors were the lack of individual equipment and of acoustic signals in moving equipment. Also some repetitions of anomalies were found especially in the most frequent ones. More research on other construction works is needed to validate some of the conclusions found in this work.

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Linking quality management, teamwork and integration to define a new model of design management for building construction

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Abstract

Over the last years, in Brazil, no matter if pushed on by competitiveness or searching for certification, contractors have worked very hard on process standardisation and quality systems implementation. As a result, the request for design management has grown and architects and design engineers have been encouraged to change organisational models aiming to accomplish such new and large market requirements. This scenery allowed a new outlook into client-designer relationship, thus renewing the most usually adopted concepts and practices of the sector.

Based on a comparative analysis stimulated by the study of French construction framework and some additional research, it is presented the basis of a new model to design management involving a group of proposals related to design and to project management, the whole being co-ordinated into this new design management model, which comprises the mechanisms for teamwork collaboration and construction players integration.

Keywords

Building construction; quality planning; design process; management

1 Introduction and analysis

The construction industry is frequently criticised as being unable to achieve the same level of efficiency as that of the manufacturing industry. Surely, the slow technological evolution, the “archaic” culture of project players, construction project fragmentation, the use of old-fashioned management methods and the insufficient barriers to prevent environmentally uncertain conditions are combining causes.

In the last two decades, the Brazilian building construction has been facing to an important and complex process of transformation of national economics configuration and of competitive conditions in the sector.

These transformations are connected to the Brazilian economical context, which has been suffering deep changes due to the economical overture and the stabilisation of the currency, imposing a vigorous process of productive re-structuring to the Brazilian industries, in order to accept the new competitive conditions of the national and global market.

In building construction, in particular, the dynamics of evolution was widened by internal changes in the sector. The lack of housing financing in the end of the 80's and beginning of 90's; the bigger transparency in the public procurement; the improvement of working conditions and the availability of work-force contributed definitely to the raise of the competition in the sector.

Motivated by the rising competition in the construction markets and by the valorisation of the customers' role in the Brazilian national economy, many firms, both contractors and design firms, have been committed to the implementation of technical and organisational innovations in their processes.

One of the main trends in the modernisation adopted by the Brazilian industry of building construction was the implementation of quality management and certification programs.

These programs started in the Brazilian building construction by the leading action of some industrials who, in the first half of the decade of 1990, were quality-certified according to ISO 9001 and 9002 standards, for the processes of fabrication of building materials and components. After 1997, the quality certification movement concerned mainly contractors and estate developers.

Another great impulse to the quality certification in Sao Paulo State was the creation and carrying on of the Programme of Quality in Housing, which regulates the contractor selection in public construction projects of CDHU (Company of Housing and Urbanism Development), an important public "project owner", making it very important the participation in this programme and the issue of QUALIHAB certificates as well1. Nowadays it is already possible to account hundreds of firms having quality certified systems all over the country. São Paulo State concentrates the highest number of certified contractors, most of them ISO 9002, but it is possible to find certified contractors in many other states from different Brazilian regions.

More recently, subcontractors and design firms motivated by the pressure of some clients and by the expectancy of being remarkable in the market have been committed to this movement for quality. So that a training programme oriented to quality management and certification specific for subcontractors and design firms came into view as well as the first certified design firms.

Although the relevance of this movement for quality has been recognised by all the involved players some evaluation recently conducted into construction sites revealed deficient results in terms of effective quality management. Some of these deficiencies were related to the formal character of quality systems and lack of planning and most of them implicated design issues.

As the production process in the building construction sector is an one-off process, the evolution of the quality management stresses the lack of transversal systems of management, project-oriented and based on the simultaneous activity of a wide range of players, looking upon to the specificity of each new construction project. Architects

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[1] The Qualihab Certification was inspired in the French system Qualibat. This certification has four levels of requirements, growing from level D to level A, which has almost the same requirements of the ISO 9002 standard.

have an essential role as product designers and that is why his organisation must be oriented towards project and clients requirements. Several times this means that the success of project quality management is strongly dependent on the characteristics of design process management.

This paper has the aim of presenting some conceptual guidelines that are intended to improve the quality systems performance concerning design and development activities as well as their interfaces with production.

2 Proposals related to design process improvement

2.1 Design as a service

Even if a design can be specified and controlled as a product, design management also requires considering the "service component", another important dimension of this activity. Melhado (1994) proposes this approach: although design quality oriented to product means only standardising and controlling plans and documents, there is something beyond their simple production and delivery. This involves the accurate understanding of the client's needs and expectations. Thus, architects should be designers, but also consultants and information suppliers to perform project co-ordination. Finally, users' needs should not be hidden by the client's requests.

Zarifian (1999) defines service as "the more efficient organisation and mobilisation of resources to analyse, understand and achieve the expected transformation of the client's activity conditions". From this viewpoint, "considering the need to interpret users' expectations and to understand the corresponding human and professional skills become critical to achieve services production efficiency. (...) It is not enough only to design the solution intellectually, if the effective transformation of the client's activity conditions is not achieved. There is often an underestimated component of services production"

2.2 Buildability

The classical project arrangement of building design teams places architects in a command position faced to other design professionals, which means that he will co-ordinate the whole design team in order to detail an architecturally designed product. In actual terms, the priority given by architects to aesthetics and formal design leads to typical difficulties of reaching team co-ordination success, such as eliminating conflicts and motivating collective work with engineers, quantity surveyors, etc.

An important factor to be considered concerns design detailing and to what extent it is oriented to production activities, in terms of real *buildability* value. Only a few architects do adopt concurrent engineering methods to combine architectural and production technology solutions. On the other hand, quality management committed architects seem to be more geared towards it.

2.3 Concurrent engineering

According to Jouini and Midler (1996), in the design process defining the problem to be solved and creating and developing its solution are associated activities. Any separation between these activities would be a source of building deficiencies as case studies developed by these authors have been shown. For instance, if this separation is done building procurement will result in low quality and difficult-to-build projects or more expensive ones, site conflicts between different teams due to design omission or contradiction etc.

Nowadays, in a building project the cooperation between involved players is a valid endeavour and it can be inspired on the practices adopted by the manufacturing industry like concurrent engineering.

Into the field of building construction, concurrent engineering can be implemented in three basic and non-excluding ways:

- a collaboration between client and design team in order to formulate the product briefing;
- concurrent design, involving data exchange systems and management methods of teamwork in design development;
- integrated product development and realization involving contractors and suppliers as well as transition activities between design and production.

2.4 Site preparation

Finally, a transition activity performed between design and execution phases is recommended. This transition can be provided through site preparation, which is defined as an *activity that is placed after the project's definition phase and establishes the beginning of its effective management, being a transition between the main design activities and the execution phase*.

Site preparation requires a weekly meeting between project players, to analyse the project's particularities, to review design specifications and to discuss each contractor's or subcontractor's contribution to design detailing and technical problems solving. The scope of site preparation includes also as one of its main objectives the development of quality plans, so allowing the participation of non-prepared contractors or subcontractors.

2.5 Design contracting criteria

Clients' role is clearer today than it was before. As the person primarily responsible for construction projects, they should define project briefing and then attribute a mandate to a design team, which must develop solutions answering to given briefing requirements. Architects, hence, are increasingly faced to very demanding and constraining clients' orders, even if some exceptionally non-restraint situations of design still exist, because of imprecise briefing. Instead of introducing a large creative freedom, these situations are sometimes the source of uncertainty, with all the resulting risks.

Alluin (1998) conducted a research about construction projects in France, which identified some contradictions in the relationship between architects and other construction project players, involving the solutions adopted in terms of construction technology, task planning, site logistics, etc.

Considering several construction players' viewpoints, Alluin's report criticises architects' low interaction with technical definitions as well as with on site production. Alluin asserts that a number of architects, thinking that their knowledge was strictly linked to creative design, left on-site work aside, and lost their building knowledge.

Alluin detected two particular configurations where design and production processes are more integrated. These are the cases of some large French architectural design firms that established a network of specialised collaborators, and also of a few medium-sized architectural design firms, which are involved in all project phases, managing the technical, financial and production aspects of construction.

According to this viewpoint, successful performance requires real co-operation between architects, design engineers, contractors and other players involved in the project. And yet, from a company perspective, the player's activity is a continual achievement, whereas, in the construction project, it is a one-off contribution, to be managed as such. Design must be recognised as *a collective and interactive process, thus requiring the co-ordination of the whole, but it must also assign autonomy spaces to each player's specialised work.*

Related to management, another important aspect of the day-to-day architect's work concerns the effectiveness of his project supervision and communication with his client.

Finally, information technology and its rising importance in the construction professions are leading architects to try to rationalise their management methods. As a result, several activities are being increasingly linked to IT, such as data archiving and document exchanges between design team members: the associated risks of inefficacy and failure must be properly managed. Hence, management methods associated with design development and control must be evaluated and contract criteria fixing how they will be required are essential to improve quality results.

3 Proposals related to quality and project management

The co-operation required by multidisciplinary work highlights the idea that project management is essential in the construction sector, but at same time, it shows the limited character of quality assurance standards. In fact, quality systems certification, one of the greatest drives that justify the growing interest in quality management in the sector, is not project-centred: his approach is focused on customer-supplier relations. Taking the construction project viewpoint, instead of each player's viewpoint, it is made clear that the "superposition" of all players' quality systems do not automatically produce a "whole project" management system, taking into account the insufficiency of players' interaction.

The French proposal of a specific standard for construction project management (MFQ, 1997) was hailed as a welcome answer to this need of co-ordination between each player's quality management (internal) and the project quality management (as a whole). In the proposed model, a prospective aim, the quality plan and management procedures have specific contents that are not the same as in the manufacturing industry; it also clearly sets apart a briefing phase that ISO 9001 simply includes amongst design activities. Moreover, the quality plan proposal stresses the needs on concurrent participation of project players, which requests strong co-ordination.

Aiming to provide a consistent and coherent Quality Plan to the whole project means integrating all the quality systems of all the players involved in the project organisation. This includes implementing new procedures oriented to client needs, as well as their integration to other players' quality systems (especially in the case of engineering design firms and contractors). See scheme at figure 1.

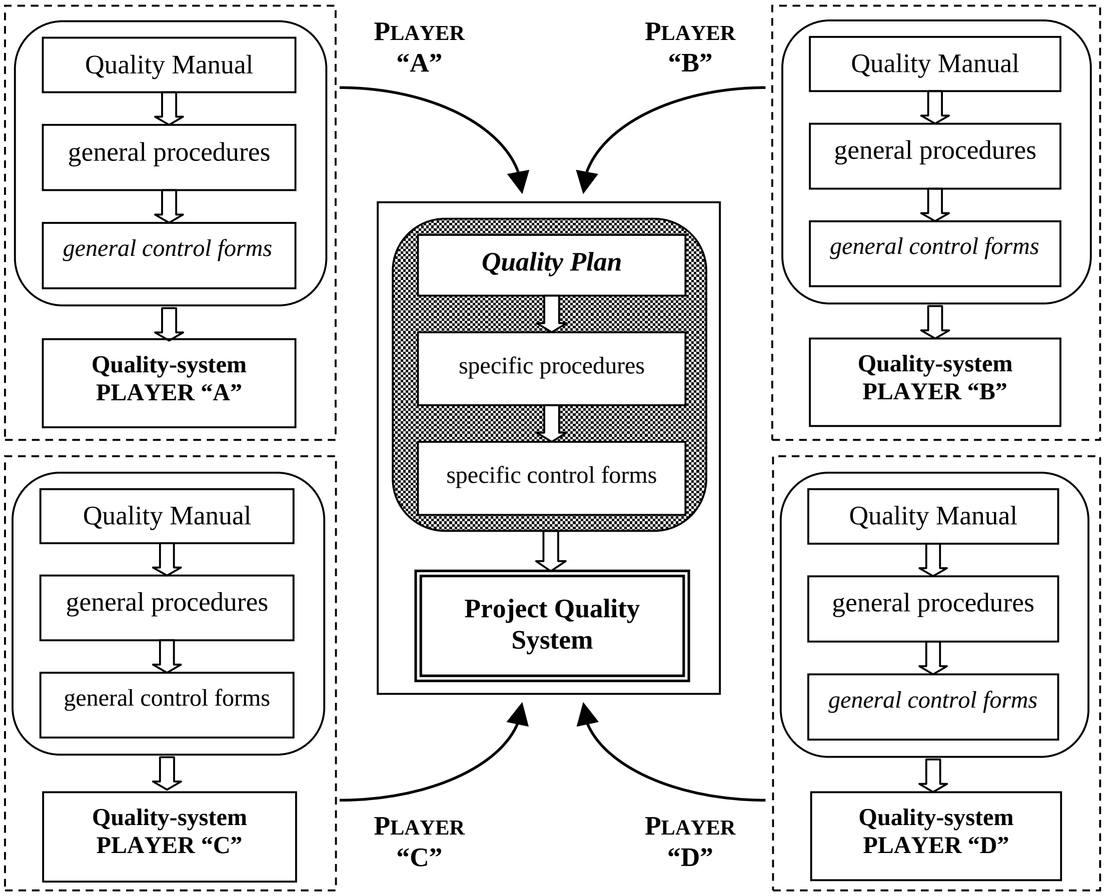

Figure 1 – The proposal of a project quality management system (Melhado and Henry, 2000)

However all the components of project management must be integrated all through the project activities progressing. As the main stages of a building project, that constitute the basics flow of project activities, it can be considered the following: project conception and feasibility, design procurement, design and developing, construction procurement, construction and facilities operate and maintenance.

Figure 2 shows this simplified flow of project activities and the placing of quality planning, concurrent design and site preparation. This constitutes the conceptual model of design management for building construction that is proposed to improve the fitting of quality management to the specific nature of the building projects.

In this conceptual model, quality management is intended to work as an integration system involving all the main project players, which is established as soon as possible (depending on the contractual nature of each project) in order to match design and production requirements and take advantage of quality planning. The adoption and effectiveness of concurrent design will also be dependent on contractual aspects.

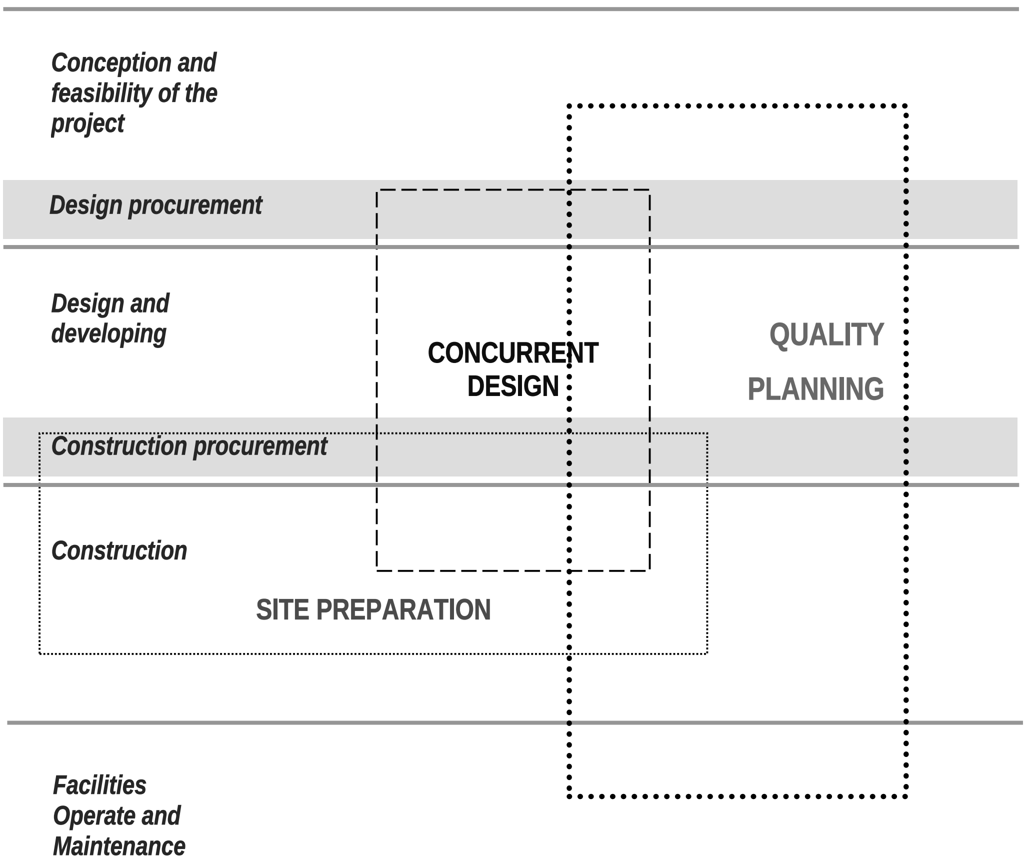

Figure 2 – The proposed conceptual model of design management for building construction (Melhado, 2001)

4 Conclusion

The Brazilian building construction industry has been increasingly committed to the implementation of the management and certification of quality in its processes.

This can be justified by the strong competition in the market and also by the move forward the rising in value of clients' role into all Brazilian industrial sectors.

Amongst architects and design engineers, this attitude changing is more recent and restricted to a small number of design firms.

Considering that co-ordinating several stakeholders is the central task of project management in the building sector, the client's organisation should appoint a number of players from permanent organisations to work as a temporary team on the specific project. In view of this, the architect's role and its management methods are strategic to perform project quality objectives.

The interest in multidisciplinary team co-ordination is especially important to all architects that aim to be quality-certified according to the year 2000 version of ISO 9001 standard, which gives strong relevance to design co-ordination. This standard establishes in particular that design reviews and validations must be programmed and registered systematically, involving all project players.

It is of paramount importance to introduce management tools oriented to the assurance of coherence among the quality management systems of all players that contribute in a project. Building construction should enhance the use of the proposed conceptual model aiming to co-ordinate and integrate the quality management of each one of the players to the project specificities, as a more efficient way of assuring the quality in the building projects.

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Quality systems remodelling with the site works preparation method and proactive co-ordination: a French experience

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Abstract

Over the last years, all around the world construction players have worried about implementing quality management principles in construction firms and sites. During this period, organisational barriers were observed in this implementation process and, particularly, managers found it difficult to transfer internal quality efforts to on-site activities. There is a range of reasons for this; nevertheless, the insufficient interaction between design and production and the lack of co-ordination of production teams during on-site works are amongst the main ones.

This paper presents and discusses a process to translate into Brazilian projects a supplementary phase to develop design and specification analysis, before starting production, which in France is called "site works preparation". In addition, the French have an experimental practice named "proactive site works co-ordination", which is also discussed.

Case studies carried out over a year and a half in France, as well as some others in Brazil illustrate the relevance and potential benefits of the proposals mentioned above. As a result, proposals related to management methods are presented for adoption in real estate and building firms, along with guidelines for implementation.

Keywords

Building; quality; construction sites; quality management

1. Introduction

In Brazil, the lack of integration between design and site teams causes several problems concerning waste in the production process and building performance in use. Non-compatible or non-co-ordinated design parts (e.g., architectural and structural design) as well as insufficient or inadequate design detailing lead to "last minute" decisions and then non-optimised solutions are adapted to solve on-site problems. This can be considered a typical statement in the construction sector and it is closely related to deficient management methods; however, what should be done to improve management and prevent interaction between construction players?

In the analysis of case studies, an important dissociation was observed between construction players' objectives and a large inefficiency in communication and documentation processes, which results from deficient co-ordination of design and site teams. Thus, a lot of detailed information was not useless and low-qualified people decided on technical solutions.

Delayed execution due to lack of information in design, changes in previously planned activities, estimated cost increase, late achievement of works, for example, are systematically found in construction and this shows how inadequate classical communication methods adopted to establish design-execution interaction are. The impossibility of anticipating interfacial problems, which are essential to production efficiency, is a long-standing phenomenon but its solution can be found in very simple procedures. The solution is linked to the promotion of a specific interaction activity between design and site teams.

It is well known that an integration effort is needed to identify inconsistent design solutions, putting designers and contractors together, e.g. to plan how to better execute the project. This kind of consideration was made by the researchers of the Construction Industry Institute (CII, 1987) and by Melhado's Doctorate thesis (1994). These authors state that decision taking must be anticipated to prevent resorting to bad solutions to solve urgent problems.

In France, "all the construction professionals know that the lack of a site preparation phase leads to risky and improvised situations, which have a questionable cost and human energy consumption due to rework needs", as synthesises a paper written by the Agence Qualité Construction (AQC, 1996).

In Brazil, this notion has also been increasingly accepted. Although very recent, a change in attitude is noticed in the Brazilian construction sector towards the improvement of quality and productivity. In this scenario, a belief concerning the importance of jointly organising and planning the production process, before starting execution, has spread. Practical application of this, nevertheless, is not yet in practice, so rework is still significant.

Aware of a similar difficulty, and having the support of some institutional groups, French construction has developed a methodology and experimentally implemented it in the sites. Amongst these methods, the authors have chosen the methods called "motivating site co-ordination" and "site preparation" to be adapted to Brazilian conditions, as they seem to be applicable in their national circumstances and faced up to their improvement needs.

"Site preparation" means "the organisation of project chosen location and the co-ordination of the players' actions in order to ensure that the whole production structure runs, with the contractual objective of materialising this designed project" (AQC, 1996).

In brief, site preparation and site co-ordination motivation aim to reach five important results in construction (AQC, 1996): to prevent poor quality; to improve professional relations; to manage building schedule and to prevent additional delays; to manage construction costs as well as operation costs; to preserve human health and safety and to protect the environment.

Definitely, it is not a matter of solving every potential site problem, but the principles of this management philosophy can help to achieve better work conditions and also to anticipate and prevent predictable situations.

2. Construction sites in France and in Brazil

Nowadays, in France, there are predominantly small-sized contractors and subcontracting is quite frequent. Regarding the latter point, the amount of subcontracting in French construction is now twice as big as that of fifty years ago, according to the data of an inquiry involving thousands of contractors. Thus, in that country, the scenario of construction sites involves a big number of players working on site simultaneously, and following quite compressed schedules – total delays do not usually exceed twelve months – at the same time that several standards and legal requirements must be taken into consideration.

It is important to mention that, since the sixties, there has been a specific function in French projects, which is called “OPC” (*ordonnancement, pilotage et coordination*) and can be translated as “site co-ordination”. Site co-ordinators in France have as basic responsibilities: the subdivision of the execution process into elementary tasks and the analysis of interference among them (*ordonnancement*); the allocation of resources needed to produce these tasks in time; the follow up of execution progress and the intervention in case of interface problems or increased delays that require re-scheduling. In small-sized projects, site co-ordination is normally attributed to the main contractor or associated with the design co-ordination function (*maîtrise d’œuvre*).

Another important function concerns technical control (*contrôle technique*), which was introduced in France in the sixties, too, and, even if not compulsory, it is very frequently found since it allows to get reduced project assurance costs.

The role of technical control begins in the design phase and keeps very active during execution. In the design phase, technical control has the role of design solutions checking according to technical standard requirements, which is not usual in Brazil, where designers are intended to be responsible for checking standards by themselves; after this, the main technical control task is related to quality control on site, similarly to equivalent practices found in Brazilian sites, but a bit more comprehensive.

Moreover, since 1994, a “safety and health co-ordination” was made compulsory to every construction project in order to prevent safety and health problems on site (concerning the use of equipment and collective protection) and also related to the building in use (e.g. it includes safety and health in maintenance operations). Thus, design must interact with safety and health co-ordination to adequate building specifications and detailing to satisfy all requirements defined by standards and legislation, preventing difficulties of facade cleaning, ceiling accessibility or floor slipping and the safety and health co-ordinator has the ultimate decision in this kind of discussion. During site phase, he has an equivalent power that allows to stop execution if safety and health conditions are not acceptable.

In fact, sometimes, the site co-ordination and the safety and health co-ordination can have opposite objectives related to schedule, for example. In addition, design detailing is a joint responsibility of suppliers, contractors and design professionals. This means site co-ordination effectiveness depends on the co-operation of suppliers and contractors but it also depends on the participation of design co-ordination, which must validate technical solutions proposed by contractors. French legislation clearly attributes the main responsibility of detailing execution to contractors, rather than consider this as a design component, since they are intended to be better skilled to establish the solutions that ensure quality in project execution.

Thus, French architects have the responsibility of supervising project execution to ensure the conformity to design but they must interact with contractors to develop consistent solutions in detailing. Particularly, in the case of interface problems involving two or more contractors, the architect and the site co-ordinator will provide the necessary specifications or plans to guide execution.

Figure 1 illustrates a typical project arrangement in France. In Brazil, project arrangement is different, especially in terms of roles and division of responsibilities amongst players. Brazilian design professionals rarely participate in the execution phase and there is no similar site co-ordination, since site managers perform a similar role; also, there is no technical control, safety and health co-ordination during the design phase.

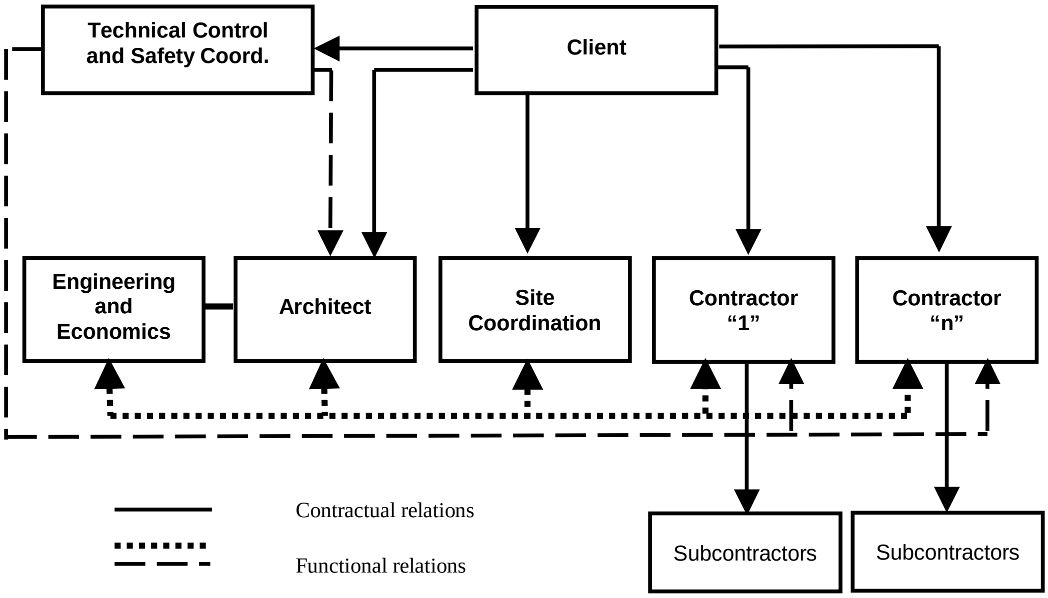

Figure 1: French project typical arrangement.

The Brazilian site manager is always on site and he is responsible for technical, administrative and safety co-ordination. This site manager is commonly on site everyday and, depending on the firm, he counts - or not - on the help of a technical manager. Finally, technical control is clearly less extensive than in France and assurance systems are not compulsory. Figure 2 illustrates typical project arrangement in Brazil. The most important deficiency concerns the relationship between client and contractor, and the relationship between contractor and designers. Differences and similarities apart, French and Brazilian realities present some identical challenges: restart the sector growth; change of competitive parameters; increasing importance given to financial management and production management; quality certification dissemination.

3. Site preparation and site co-ordination motivation

3.1 Site preparation

Site preparation is defined as an activity that is placed after the project definition phase and establishes the beginning of its effective management, being a transition between the main design activities and the execution phase. An important characteristic of site preparation is that it begins exactly before the moment when real expenses start to replace production costs estimation.

Site preparation requires a weekly meeting between project players, to analyse the project particularities, to review design specifications and to discuss each contractor's or subcontractor's contribution to design detailing and technical problems solving. The philosophy of site preparation also has as one of its main aims the understanding of product design and technological choices, thus allowing the participation of non-prepared contractors or subcontractors.

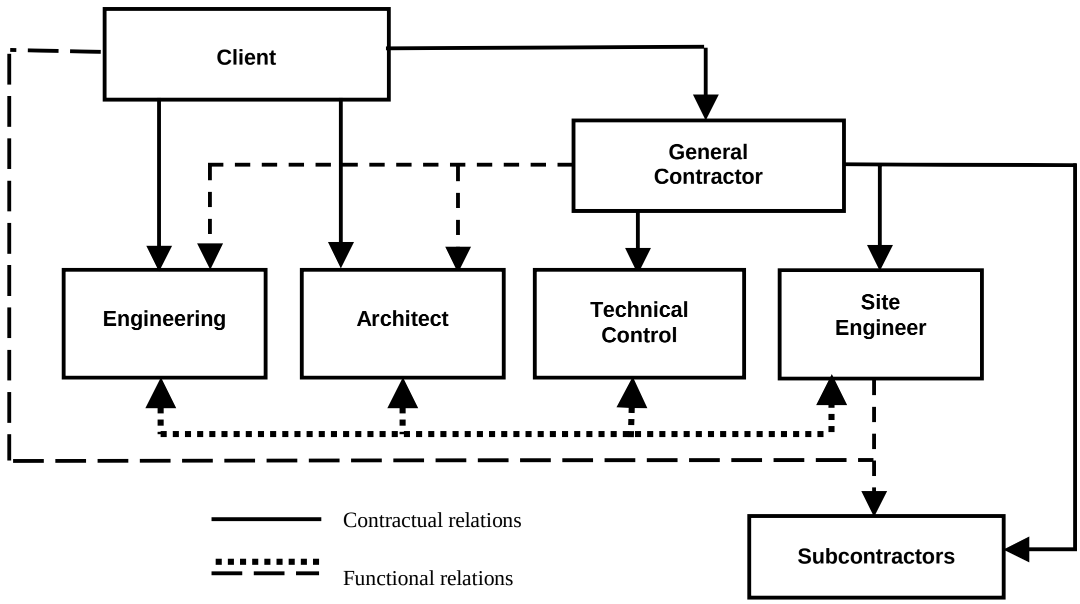

Figure 2: Brazilian project typical arrangement.

Its adoption in the French projects is increasingly common and, even in the case of small-sized ones, where a period of at least four weeks is necessary to previously examine each of the execution tasks and all the interfaces among them. This work, however, does not finish after these four weeks of preparation; in fact, it must be conducted along execution while interface problems still exist.

The total duration of site preparation depends on the project size and nature and this activity during execution shall not be misinterpreted as being the same that motivates site co-ordination. Site preparation means working in groups and producing design detailing and design for production, which will lead to collective decisions and provide very oriented information to ensure quality during execution, in a co-operative ambience and without conflicts or unpredictable problems. During the site preparation phase and according to one of its main principles, trust relations may be established between all players concerned. This preparation period may also contribute to identify and solve non-answered design questions, to obtain the commitment of each participant and to well understand final product quality requirements.

The concept of “Project-Firm” (Descours et al., 1996) is essential to define objectives, actions and procedures co-ordinated by the same person in charge. Those authors state the need of an ephemeral but strong organisation founded on quality management principles that emphasise motivation and commitment, throughout the execution phase.

The meetings are jointly co-ordinated by the design co-ordinator (generally, the architect), the site co-ordinator and a client representative, who will discuss with a number of contractors (up to fifteen contractors each meeting). The safety and health co-ordinator and the technical controller will be present, if necessary.

Site preparation intends to anticipate and solve execution difficulties, saving time and, then, joint decisions are scheduled. About this specific matter, French public projects are compelled to develop site preparation and a large portion of the private construction sector also performs it.

In the Brazilian context, similar procedures should be implemented so as to reduce waste, promote national standards development, encourage quality certification, etc.

3.2 Motivating site co-ordination

After several case studies in France involving the implementation of site preparation, three relevant deficiencies were identified: lack of integration between product design and production; problems due to information transmission; lack of co-ordination during site execution. Efforts made during past stages do not assure production efficiency.

The method proposed aims to contribute to the implementation of very good decisions during site preparation. For this purpose, motivating site co-ordination involves: the management of decision-taking; emphasis on quality control and the integration of cost control and safety control into quality management; delay respect; efficiency of information system to avoid the risk of non-compatibility in design..

The method of motivating site co-ordination intends to establish trust among construction players, which can prepare to control the execution by themselves, to internally verify quality, etc. This kind of procedures can eliminate several control forms to be filled in, such as their correspondent analysis, thus reducing the need of very specialised personnel to perform classical “quality control”.

Site co-ordinator must participate in different stages of design, in order to optimise final solutions: design review and validation; choice of subcontractors; site preparation; execution; final building acceptance.

Despite the increasing number of quality-certified firms, there are a lot of French contractors that still work without a consistent organisation and who lack internal management procedures – in these situations, motivating site co-ordination has an important role concerning management of sub processes in harmony with the whole project management.

3.3 The meetings during site preparation

During site preparation meetings, information transfer and obscure points related to design are jointly organised by the design co-ordinator and the site co-ordinator. All the data are registered in technical reports or meeting minutes.

According to the orientation of a well-recognised French guide (Club..., 1993), site preparation must include three main stages, thus involving at least three general meetings (and several other meetings without some of the project players):

a) **First stage (site preparation opening) – basic matters:** the design introduction by the design team to site personnel, highlighting its most important characteristics, the difficulties involving execution and technical solutions adopted, which can be criticised and modified by contractors proposals; the elucidation of each player's role and responsibility, stressing the necessary formality concerning decision-taking; the introduction of procedures that will guide site preparation as well as communication resources and forms that will be adopted; the evaluation of players' expectations and wishes concerning the project; the constitution of work teams (e.g., structure and building systems; internal partitions and piping; finishing) to design detailing, interface analysis and site lay-out development; the proposal and validation, after discussion, of an interface check list.

b) **Second stage (harmonisation and evaluation meeting) – basic matters:** the validation of the design for production detailing, based on work teams proposals; if necessary, the constitution of a special work team in charge of complex items detailing; the evaluation of partial results from site preparation and work teams synergy; the formal report of completed and uncompleted activities, in order to commit people with predefined objectives.

c) **Third stage (site preparation completing) – basic matters:** the checking of site preparation completion; the validation of all documents produced; the discussion and validation of site preparation results and signature of meeting minutes.

Surely, large-sized or very complex sites require more detailed site preparation than ordinary ones; contractors' and subcontractors' characteristics are also influencing factors, since well-organised firms are capable of good design detailing; in case of very small contractors' organisations, designers' participation on detailing shall be dominant.

Figure 3 shows a typical sequence of meetings, during the phase of site preparation (Club PACA, 1997).

4. Case studies

In France, four case studies were carried out for a year, aiming to evaluate the results deriving from the implementation of the site preparation methods and of motivating site co-ordination, which were developed by the Construction Quality Club of Isère (Club..., 1993 and Masure; Henry, 2000). Concerning these four projects, we followed all the meetings related to site preparation, besides the methods and tools that were used to solve problems, as well as the results achieved by site co-ordinators. There were, amongst these cases, three public construction projects and a private one.

In France, architects are not only responsible for construction product design, but they also participate on site and keep very active until the building construction ends and is accepted by the client. Although most architects would not be able to solve some production-related problems, this deficiency may be counterbalanced by integration and co-operation skills in teamwork. As nobody is fully skilled at technology or production management, it is precisely there that quality management concepts can be brought to bear. As design co-ordinator, the architect significantly helps during all the site phase of the project.

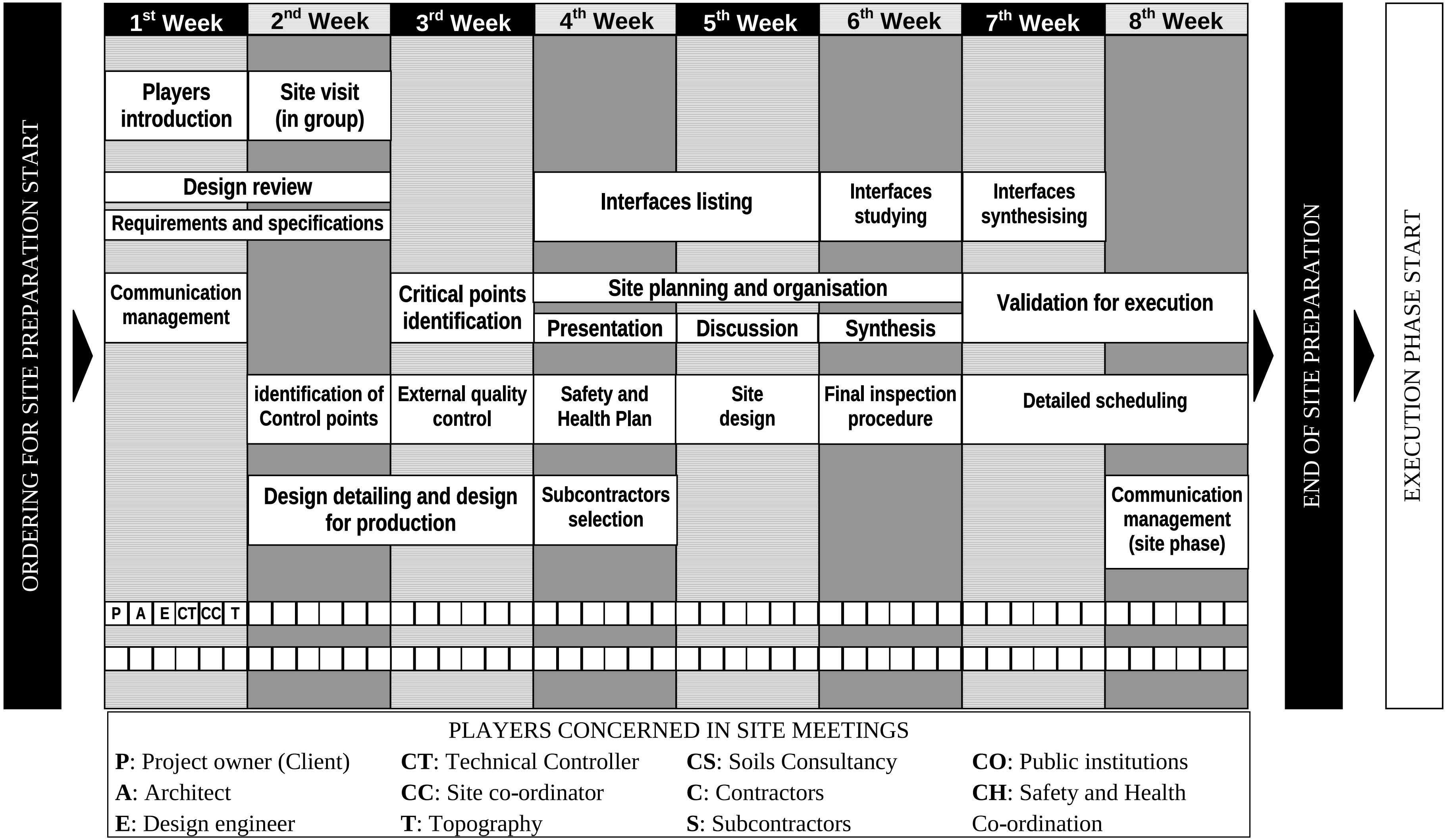

Figure 3 General planning of typical meetings during the site preparation phase.

It was observed that, sometimes, the design co-ordinator could also be the site co-ordinator in French projects. In brief, the three possibilities that were identified concerning this role show that an engineer from the main contractor, an architect issued from the architectural office that designed the building or an independent engineer can all be site co-ordinators, thus leading a team that includes a client representative, designers, contractors, subcontractors, the technical controller and the safety and health co-ordinator.

In these case studies, even if each project has particular characteristics, such as size, complexity and contractors' organisation degree – from a well organised, quality-certified contractor to small-sized and informally organised ones, general results were positive in all the cases. One of the reasons for these favourable results concerns hard work performed by site co-ordinators, determinedly supported by clients. The results they achieved include interfaces number dropping, productivity improvement, initial scheduling followed and rework decrease. The improvement in terms of relationship among players must also be emphasised, specially concerning design co-ordinator and site co-ordinator, the enlarged motivation of personnel and increased designers commitment.

Site preparation meetings were performed on site and, aiming to communicate decisions properly and helping to register construction development, co-ordinators wrote minutes that were quickly distributed to all players concerned. As true "round tables", site meetings ensured better-anticipated comprehension of design specifications, buildability and interface problems. Similarly, motivating site co-ordination ensured execution according to decisions taken during site preparation, leading contractors and subcontractors to apply standards and procedures and to perform pre-established controls. It must be highlighted that project players, even having conflicts, were organised as genuine quality teams, with clear objectives, mutual respect and collective sense.

In Brazil, three case studies, carried out for a year and a half, showed that the evolution occurred along two years, when certification programs started to definitely influence the construction sector, which is not yet enough to facilitate site organisation and control. The lack of national standards of building performance, the lack of accurate design and execution procedures, the lack of clients' commitment to quality, undefined responsibilities of each player and construction-specific culture remain significant.

Nevertheless, relevant evolution was internally observed in Brazilian contractors, concerning design process co-ordination and the standardisation of execution procedures, albeit without solving the integration between design and execution. Although each site has a full-time engineer to co-ordinate execution, designers do not systematically contribute to site decisions and very rarely go to the site aiming to solve design detailing problems. At the same time, site managers are not systematically involved in design development, even if the projects studied are built by private project owners where estate developers and construction managers work together in the same firms.

In Brazilian projects, there is not a specific phase of multidisciplinary site preparation, as observed in France. Design plans arrive very late and site managers only have few days to prepare execution. This means a situation of great uncertainty that leads to rework and additional costs. A very important difference was found in terms of legal and contractual precision, which can block some management initiatives. Brazilian construction remains fond of informality and exceptions prior to the rules.

5. Preliminary guidelines to the Brazilian translation of some French practices

Considering the Brazilian construction context, which comprises construction-specific culture of the players and construction industry deficiencies – like the lack of professional skills, the lack of production know-how, the lack of standardisation and the lack of subcontractors qualification – it must be highlighted that changing processes first require all favourable conditions in terms of clients', designers' and contractors' attitudes; thus, a successful application of the guidelines presented above in the text requires players' motivation and commitment to implement the proposal.

Some basic steps of this implementation are: review of French management tools with regard to the Brazilian context; motivation of representatives in construction associations to implement these French concepts and tools; surveying of "experimental" projects where the concepts can be applied and where these players shall participate; evaluation of first results and review, analysis of limitations and of the proposal applicability; diffusion of the motivating co-ordination method, associated to an evolution concerning definition of players' roles (contractor, subcontractor, architects and engineers).

Guidelines concerning the client

It is proposed that clients must be committed to quality management and must have a more active participation during all the project phases, especially after legal approval, aiming to: adopt the multidisciplinary approach, throughout anticipated contract of all design specialities; contract designers to introduce design principles faced up to site teams, to visit the site and contribute to collective decisions; precisely define players roles and responsibilities.

Guidelines related to contractors and designers

Motivating site co-ordination must be performed by skilled professionals and the specific project factors, such as contract type, size, or client requirements can influence the choice of a professional. In Brazil, he/she should be typically the site manager, but an independent manager will eventually be preferable, according to the situation.

In all cases, the constitution of a site team is essential from the very beginning of site activity and the definition of periodic, well-organised and well-documented site meetings.

The design detailing called "design for production" should be performed by building designers (architects or engineers) and consultants but also by the site manager, the subcontractor or the supplier, according to the situation.

Guidelines to site preparation and site co-ordination motivation

Some of the most important elements concerning this are: collective site visit to start site preparation; discussion, development and validation of design detailing; critical points identification, through the analysis of interface problems; self control preparation, in order to simplify quality control; clear and concise minutes and fast communication of decisions taken; feed-back implementation involving all project players, in order to achieve continuous improvement.

6. Conclusion

This paper presented a brief discussion on some French management concepts that can improve the relationship between design and site teams, based on a comparative analysis of French and Brazilian construction contexts (considering social, economic and legal aspects). Case studies helped to develop a process of observation, analysis, reflection and formalisation aiming to contribute to the translation and adaptation of French proposals to the Brazilian context.

Albeit in France the management philosophy presented was created to be applied in public construction projects, the same guidelines would be also valid in private projects, if particular characteristics of the client and the main contractor, as well as the project strategy requirements, are considered.

An innovative management procedure requires changes in attitude from all players concerned. The fear of changing is natural but necessary to overcome rejection of collective work and joint decisions, seeing evolution as an opportunity of professional growth. As construction projects lead to team renewal, the risk of losing information, methods, and management tools, must be fought by collective work and systematic documentation.

The definition of subcontractors from the very beginning of the project execution is also essential to the success of the method. Because of this, we propose procurement systems that consider not only tendered prices, but also experience and commitment to quality. It is thus useful to include management and execution procedures and quality control requirements in the contracts.

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Developing tools for a management system to improve the quality of a facility

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Abstract

Quality can have different connotations in the phases of the life of a facility. The meaning of, and requirements for, quality can vary in the planning, design and construction phase, the operating and maintenance phase, and the rehabilitation phase.

Two separate research programs are described as case studies to better understand quality and to consider the development of tools for a management system to improve quality. In one case, a very extensive study of the life cycle costs and quality of many military facilities were analyzed. In the other case, a small study of the quality and life of roofs was undertaken.

The performance, durability and conformance to requirements of a facility are critically important design considerations if a facility is to meet the stated and implied requirements of the user. Obviously, other factors such as aesthetics and perceived quality should also be considered. These factors influence life cycle costs since operating and maintenance costs will increase if critical or costly components of a facility have shorter lives than others and require replacement during the service life of a building.

Keywords

Case studies; construction; facilities; management system; quality

1 Introduction

Factors that determine quality requirements can have different connotations during the phases of the life of a facility. During the planning, design and construction phase of a facility, the relative strength, or grade, or the degree of excellence of the materials and components used in the construction of the facility can be used fairly effectively to measure conformance to requirements and therefore define the quality of the constructed facility. Positive or negative decisions on quality can be made by considering, for example, whether the material or product conforms to the specified requirements that are based on a relative measurement of grade or strength.

However, these measurements are often considered inadequate in portraying quality for the whole life of the facility, particularly in the operating, maintenance and rehabilitation phases of the facility, for several reasons. One reason is that, during the service life, the facility must meet the needs and expectations of the users and customers. Another reason is that the life span of critical components of a facility can have relatively short service lives and this should be considered in comparison with the overall design service life of the facility. If the service lives of individual critical components vary, and result in apparent continuous repair and maintenance, the facility will be perceived by the user as one which lacks quality and this could lead to adverse psychological effects. In a perfect world the maintenance or replacement of critical short life components should therefore take place simultaneously at certain intervals. It is therefore necessary to consider the whole life of a facility, particularly when sustainability is considered.

The needs of the users and customers of a construction facility can be best met by paying special attention to detail in the design phase of the facility. As shown in figure 1, the majority costs for a facility are incurred during the operation, maintenance and rehabilitation (O, M &R) phases. The ability to influence these costs however, is greatest during the design phase of a building's life cycle. The components of a building can be divided into two categories: critical and non-critical. Failure of a critical component could result in the loss of use of all or part of the facility whereas failure of a non-critical component typically results in an inconvenience to the occupants. The maintenance and rehabilitation costs associated with critical components can amount to a significant percentage of the overall O&M costs depending upon the quality of the critical components namely, the building envelope (including windows, doors and façade), the roof, the electrical and HVAC (heating, ventilation and air conditioning) systems.

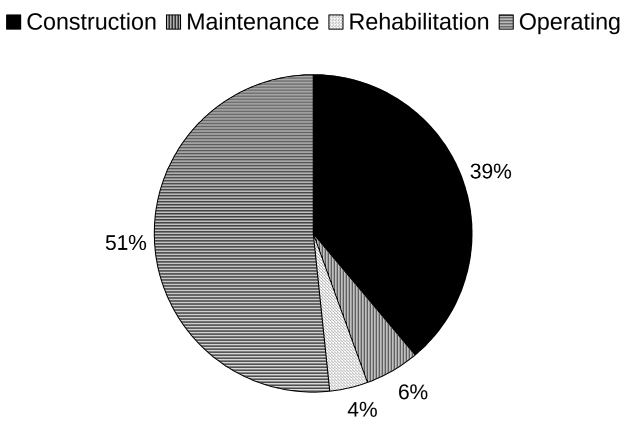

Figure 1 - Percentage of building costs associated with life cycle phase for a public sector building.

Recognising this significant percentage of overall costs, research programmes such as the Building Envelope Life Cycle Asset Management (BELCAM) project, co-ordinated through the Institute for Research in Construction in Canada are aimed at developing tools for asset managers to use to help predict the service life of critical components. The first phase of this particular project undertook an extensive study of roofing systems (Kyle, Vanier & Lounis, 2002).

2 Quality Considerations for Asset Management

Regardless of ownership, public or private, an asset manager needs to consider the whole life costs of a building. These costs include design, construction, operating, maintenance and rehabilitation costs. They may also include interest and land acquisition costs and demolition costs. Many factors dictate the initial design of a building. These include the criticality of major components, the level of maintenance associated with each component, the required service life for the building, and the money available to design and construct the building.

The criticality of a component is determined by the impact its failure would have on the operation of the facility and the effect it would have on personnel occupying the building. High criticality implies that failure would result in the loss of use of the facility. The failure mode may be as severe as danger to life, as in the sudden collapse of the structure, or it may result in interruption of use. Levels of maintenance for a major component can range from none or “maintenance free” to extensive, which entails complete replacement of the component (Canadian Standards Association, 1995).

The service life or "design service life" is defined as the period of time during which the building or its components will perform without unforeseen costs or disruption for maintenance and repair. Typical service lives for critical components are given in table 1 below.

In life cycle costs assessment or analysis, the design process becomes iterative as the asset manager tries to balance the required service life of the facility, the desire to have critical components that will minimise the impact of failure and reduce O, M&R costs with a limited design and construction budget. The asset manager knows instinctively that money well spent on design and construction will minimise O, M&R costs. How can the conflicting needs be met and a quality facility be built?

2.1 Quality in Design

The performance, durability and conformance to requirements of facilities are critically important design considerations if a facility is to meet the stated and implied requirements of the user. Serviceability and reliability of the building and its components are also important. Finally, factors such as aesthetics and perceived quality should be considered. What does each mean at the design level and can each of these considerations be measured?

By defining the intended primary function, the performance of a building is defined. The design may include a secondary role for the facility. It is important to consider the likelihood of obsolescence at the design stage, as this may be the overriding consideration for service life determination. Performance is linked to the second factor, durability, or how long the building and its components are expected to last in relation to the design service life. The service life is affected by the quality of materials, the design level, work execution, the impact of the indoor and outdoor environment, the level of use and the maintenance level. Conformance at the design stage takes into account the degree to which the design conforms to the owner's original statement of requirement.

Table 1 - Component design life

Critical Component	Description	Service Life (years)
Foundation & slab [1]		60
Supporting structure [1]		60
Exterior walls[1,2]	Pre-cast wall systems Metal/glass/structural glazing REC/concrete block/brick	20 – 40 20 – 25 60
Exterior cladding [3]	Metal Wood Stucco	20 – 60+ 20 – 60+ 20 – 60+
Windows [1]	Metal frame & sash Wood frame &/or metal sash Vinyl frame/sash Sealed double glazed	20 – 60 25 25 20 20
Doors [3]	Metal frame/door Wood frame/metal door Wood frame/door	20 – 60 25 25
Roof [4]	Built-up/modified bitumen Other membranes Metal Asphalt shingle Asbestos tile	20 15 25 15 20
HVAC [4]	Plant Piping	20 20
Electrical service [4]	Plant Lighting/wiring	20 – 40 20 – 40

[1] CSA 478-95 [2] (BS 7543,1992) [3] (Hodges, 1999) [4] (White, 1992)

Serviceability/maintainability and reliability are linked to the future O, M & R of the facility. It is important that consideration in the design be given to the future maintainability of building components, especially critical components. Reliability is influenced by the extent to which proven methods, materials and equipment are considered as they relate to the building performance and function.

Finally, aesthetics and perception are important to the design. The degree to which aesthetics are a design consideration must be in accordance with the intended use of the facility. The design must then be considered subjectively from the "eyes" of the end users. Will it be perceived as a "quality" structure by both maintainers and the occupants?

2.2 Quality in Construction

Quality in the construction phase is best defined by conformance to the requirements of the drawings and specifications. One method of determining the degree of conformance, and hence quality, is to examine the incidence of "non-conformance". This is frequently done by identifying the number and cost of design and site changes to the project. Measuring schedule growth and cost growth can also be used as a measure of conformance.

2.3 Quality in Operations & Maintenance

The consideration of quality in the operations and maintenance (O&M) phase is often overlooked in the design and construction phase; however, the best designed and constructed building will not reach its design service life if it is not well maintained. Conversely, an average quality building can easily exceed its service life if a quality O&M programme is in place.

Quality in the O&M phase can also be considered in terms of the same seven factors used at the design phase. A quality O&M programme will ensure that the building's performance is, as a bare minimum, sustained with normal maintenance. This can be measured against a condition index, which provides a measure of the actual physical condition of the building. As with design quality, durability is related to performance in that the actual service life of the building can be compared to the design service life. Well-planned, regularly scheduled routine and preventive maintenance is essential to quality O&M.

Serviceability can best be monitored by assessing the level to which buildings are maintained in accordance with the manufacturer's recommendations and the approach the asset management organisation takes to planning and scheduling building code upgrades and strategic mid-life rehabilitation.

Reliability is most often thought of as a measure used primarily in the manufacturing industry. It can be also be used as a measure of quality in asset management by comparing the life span of critical components to the average service life of comparable components. Quality is thus measured by the level to which component failure is better or less than the average.

Determining the appropriate level of funding for aesthetics as opposed to O&M is also important to determining quality in O&M. Priority funding should be allocated for routine and preventive maintenance with aesthetic funding allocated at a level appropriate to the performance of the building.   Finally, perceived quality is a measure of how the building occupants perceive the quality of the O&M of the facility.

3 Towards a Management System to Improve Quality

A management system to improve the quality of a facility from the customers and users perspective is required. A good system can only be created following extensive studies of life cycle costs, the service lives of critical components, and the design service life of the facility in an attempt to quantify quality and its impact on whole life costs. The needs and opinions of users and managers of facilities should also be elicited and considered.

Two separate research programs (Christian, Newton, & Gamblin, 2001 and 2002; Christian and Newton, 2002) have been conducted; one program is an initial step to investigate life cycle costs and how they relate to quality, and the other program investigated the contrasting operating and maintenance approaches of the roofing assets of two public sector organizations.

It is hoped that when the results of these research programs are known and evaluated an initial draft management system to improve the quality of a facility could be created within the fairly narrow confines of the categories and components of the facilities studied.

4 Case Studies

4.1 Military Building Study

The research presented in this section is part of a larger research programme in which historical cost, usage and design data were collected for 215 buildings on military bases in Eastern Canada. The data were obtained from old property record cards, the current asset management database, development files, old project files, original contracts on file, preventive maintenance (PM) records, historical cost data from the construction engineering management information system and base construction engineering management system, in addition to current cost data and "as-built" drawings. Two of the categories of buildings studied were administration and residential facilities.

The study of these two types of buildings proved particularly interesting. Both categories had buildings with a low occupancy/usage because these buildings were occupied primarily by military units that were away on military operations during part of the year. Hence, the buildings were only partially occupied for up to six months at a time and required minimal M&R. There were also buildings where the M&R exceeded the average for the category due to the high profile of the facility and its occupants or due to internal re-organisation. In addition, both of the administration and residential categories had a wide age range of buildings and the newer buildings require substantially more M&R expenditures than the older buildings for the same initial period. The impact of these factors is shown in figure 2 for administration buildings.

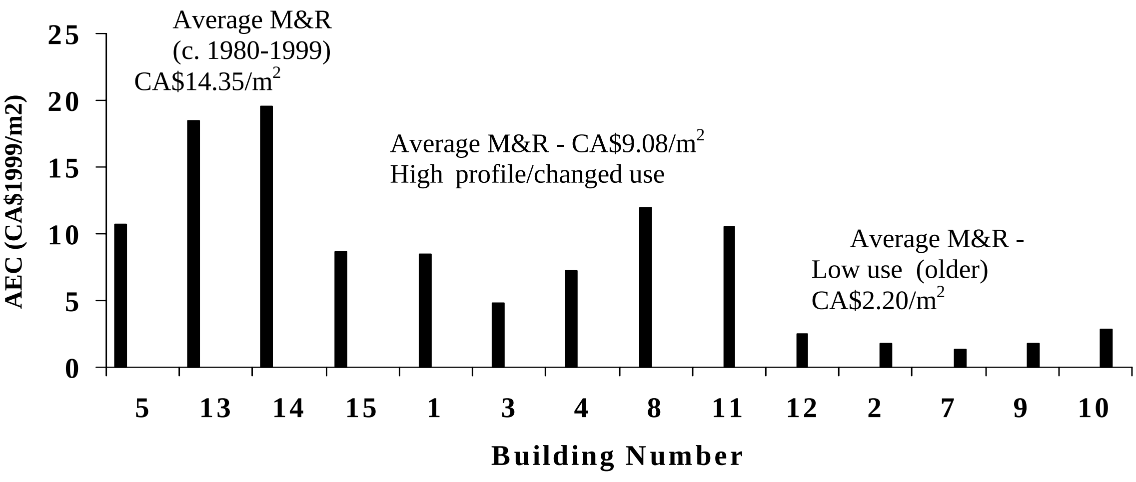

Figure 2 - Comparison of annual equivalent maintenance & rehabilitation (M&R) costs (AEC) for administration buildings by age and use.

Another criterion that set these two categories of buildings apart is the profound change in design that has occurred over the decades. The older residential buildings, constructed between 1955 and 1965, were designed with a secondary function of an administration or institutional building. As newer residences were constructed in the 1970's & 1980's, many of these buildings were rehabilitated and converted to the secondary function as it was shown to be more economical to rehabilitate the facilities than to demolish them and design and construct a new building with the same level of design quality. Rehabilitation of a building to include roof, window and exterior door replacement; upgrading of the HVAC and electrical systems and complete interior renovations was found to have an approximate cost of $\$460/m^2$ in constant 1999$. The cost to construct a new facility, based on the average of all administration buildings would have been $\$1300/m^2$ in 1999$.

As shown in figure 2, the average AEC was $\$2.20/m^2$ for the low use or average profile buildings and $\$9.08/m^2$ for the higher profile buildings. This case study showed that while quality is a major factor in life cycle costs, the level of use as well as the type of occupant also plays a significant role in determining the level of funding for M&R.

4.2 Roof Case Study

Roof maintenance management systems (RMMS) were studied for two public sector organizations to determine whether or not the quality of an O&M programme has an effect on the actual condition of the organization's roofing systems. The study focused solely on flat and low-slope roofs. This research is part of the Building Envelope Life Cycle Asset Management (BELCAM) project and co-ordinated through the Institute for Research in Construction in Canada.

Visual inspections were conducted on the flat to low-slope roofs of both organizations and a roof condition index (RCI) was computed using a computerized maintenance management called MicroROOFER (USACERL, 1995). The roof condition index is a number from 0 - 100 where "0" indicates a failed roof and "100" represents a roof with no distresses or defects.

The first organization investigated was the University of New Brunswick (UNB). UNB has 35 buildings, totalling 150 flat and low-slope roof sections on its Fredericton campus encompassing over 420 000 ft^2 (39 000 m^2) of roof area. In this case, a roof maintenance management system is not currently utilized although, to some extent, some of the principles behind it are used.

UNB relies mostly on hard copy documentation, in the form of specifications and roof plans, to identify its roofing assets. Many gaps exist in the body of knowledge when attempting to identify roofing system components (membrane type, insulation type, etc.). These hard copy documents are also difficult to manage. Updating the documentation also poses problems, as there is no system in place to ensure information is accurately updated.

Routine inspections are not undertaken at UNB. Since the roofs are not inspected, it is difficult to determine which roofs need repairs or need to be replaced. A lack of programming for roofing system projects (repairs or replacement) can lead to problems in the future when more roofs are in need of repairs or replacement than there is money available to fund and implement the repairs.

All major repair or replacement project work is contracted out at UNB. An in-house project coordinator has the responsibility of overseeing the roofing work even though he/she may have little knowledge of roof construction. This allows the contractor significant latitude in what is provided and how it is provided (Bailey and Adiguzel, 1999).

The second organization investigated was the Combat Training Centre (CTC) Gagetown, located in Oromocto, New Brunswick, which has a flat and low-slope roof inventory of 156 buildings, covering over 1.43 million square feet (133 000 m^2) of roof area. In this study, 101 roof sections on 15 buildings were investigated, totalling over 510 000 ft^2 (47 000 m^2) of roof area. A RMMS is fully utilized at this location.

Roofing system components are identified in a more convenient and centralized manner. Buildings are identified on spreadsheets along with information pertaining to the roofs of each building.

Inspections, both external (visual) and internal (Capacitance Radio Frequency Scanning and Infrared Thermography), are regularly undertaken by the organization. Based on a combination of the age of roofing systems, their leak history, and regular inspections, the organization develops future plans for their roofing assets. It decides what needs to be repaired, what needs to be replaced, and when these plans need to be executed while keeping in mind that the objective is to maximize the service lives of the roofing systems and minimize costs.

Roofing repair and replacement projects are contracted out by the organization. It is a contractual requirement that the contractor be certified by the supplier of the roofing membrane. A qualified individual, separate from the in-house project coordinator, and experienced in roofing system construction, oversees the construction of the roof. For this reason, the organization is assured that it is getting a quality roofing system.

The condition of the roofing systems of the two organizations was determined from visual inspection. The impact of the quality of a RMMS is shown in figure 3 for the two organizations.

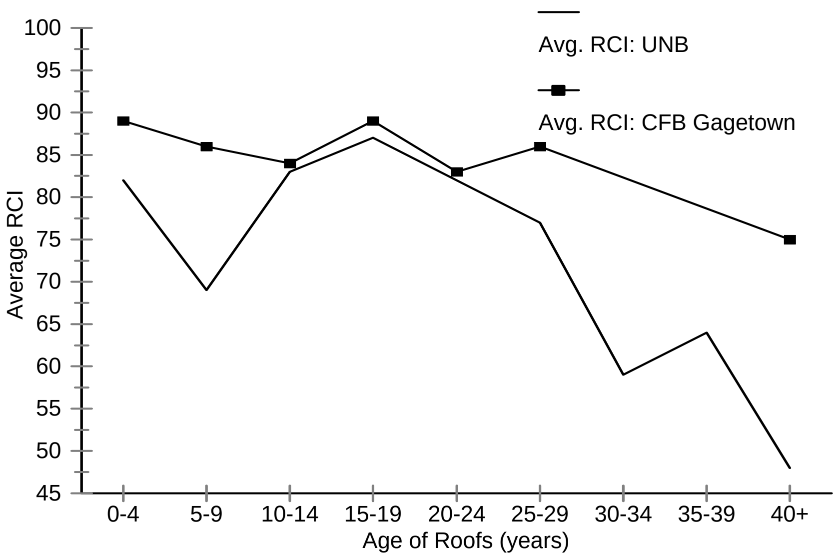

Figure 3 - Roof Condition for UNB and CFB Gagetown

As can be seen, the present overall condition of CFB Gagetown roofs is much better than those of UNB. It is suggested that the variances in both the overall condition of roofs and the rate of deterioration of roofs is due largely to the differences in quality of the roof maintenance management systems of the two organizations.

In order to extend the service lives of roofs, design, construction and O&M need to be considered. Roof design is recognized as one of several factors that can lead to the success or the demise of a roof. Even if a roof is properly constructed, flaws and inconsistencies in the roof design and details, such as roof flashings, will result in poor performance. This leads to roof leakage, reduced energy efficiency, and possible structural failure. In order to assure quality roof design and construction, all design and construction contractors should be pre-qualified. The architect or engineer should be registered professionally.

Performance is greatly improved if a reputable and capable roofing contractor is awarded the contract (Bailey and Adiguzel, 1999). It is beneficial to stipulate that the contractor must be certified by the roofing system manufacturer to install their product. This will ensure that the contractor has had training on how to properly install the product. It is important to have a quality assurance (QA) program in place to ensure that the contractor's quality control (QC) program is functioning properly and that the specified end product is adequately realized. QC enables the contractor to manage, control, and document its own activities so that it complies with the contract requirements. This can best be done by hiring a qualified, third party QC inspector. With a roof inspector present, the contractor can be expected to perform the best quality of work. A high quality roof maintenance management system will ensure that roofs reach, or surpass, their design service lives.

5 Conclusions

Factors, which determine the quality requirements during the phases of the life of a facility, can have different connotations. The varying service lives of components in a facility can influence the perception of quality by users and facility managers.

Annual equivalent maintenance and rehabilitation costs need to be considered as well as design and construction costs when considering the overall quality of a facility over its entire service life. Maintenance management systems of the building envelope are essential to improve the lifetime quality. Knowledge of costs and the implication on costs and quality if maintenance management systems are used are essential before a management system to improve the quality of a facility can effectively be introduced.

6 Acknowledgements

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The integration of quality and safety and health systems on a Football Stadium project – a practical case

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Abstract

The European Football Championship that will take place in Portugal in June 2004 requires the construction of several new football stadiums according to the new concepts of the UEFA. The construction of the new stadium of Sporting Club of Portugal is one of the biggest ones, and a professional project management team is in place to ensure that all the goals are achieved mainly on Costs, Planning, Quality and Safety and Health.

This paper aims to present the approach implemented, in particular on what concerns the integration and implementation of Quality and Safety and Health Management Systems. Basically, this paper deals with the contractual requirements made for the Supervising Team and for the Contractor, the compatibility between all the stakeholders and the strategy and main obstacles that have been detected during the implementation phase of the Project. A special focus is made on the main benefits that were achieved in terms of the functionality and optimisation of the main resources by means of the integration of Quality and Health and Safety issues.

Keywords

Construction; quality; safety and health

1 Introduction and analysis

The new Stadium of Sporting Club of Portugal (SCP) under construction in Lisbon will have a seating capacity of 50,000 people and 1,500 car parking spaces. The Project includes, in addition to the Stadium, a Family Entertainment Centre - FEC, a multipurpose sports complex with gymnasia and swimming pools, and the office building of SCP headquarters. The total investment amounts to approximately 130 million Euros, with a gross area of construction of approximately 170 000 m^2.

The complexity of this development brings challenges for the entire area of construction, particularly in respect of requirements for the management of professional Quality and Safety and Health.

2 Legal and regulatory framework

The integration of European Union Directives related to Safety and Health, specially during the last decade, introduced a number of requirements in the Portuguese Law applicable to all those involved in planning and construction. In compliance with those legal obligations, several requirements of Quality and Safety and Health were laid down within the scope of the Management of the Development/Safety and Health Coordination, with the agreement and the approval of the Owner, which should have been met and subsequently assessed in the public tenders for the Supervision and for the various Contracts.

The Safety and Health Plan Prepared during the Planning stages was also included in the various public tenders, thus becoming a contractual document the compliance of which could not be challenged or invoiced as extra costs by the Contractors.

A Quality and Safety (Q & S) Policy to be followed by the Owner was also included from the very beginning, showing to all those involved a public commitment to those matters.

The objectives that were envisaged with those requirements were as follows:

- to ensure the existence of contractual obligations that included and enable the control of the performance of the Supervision and of the Contractors in respect of Q&S;
- to assess the existence of a Q&S culture in the bidding Companies;
- to assess and make compatible the Q&S Management Systems of the Contractors with the systems of the Supervisory entities;
- to assess the human resources and the materials used in the implementation of the Q&S Management Systems.

To facilitate the understanding of the concepts in which the contractual requirements were based, some of the most important of these requirements are listed below:

- the obligation of the bidders to submit a Quality Management System that conforms with the requirements of the ISO 9000 standards and a Safety and Health Management System based on those same requirements;
- the obligation to show a description of the Q&S Management Procedures that the bidder wishes to implement in the Development;
- the Safety and Health Management System should make the requirements of the mentioned regulations compatible with the Portuguese Law, in particular with the integration in the portuguese law of the "Construction Sites Directive";
- the bidders should indicate the human resources to be employed, with reference to their professional experience, expected to perform duties directly related to the implementation of the Q&S Management Systems.

It should be mentioned that at this stage of the Project there was no clear intention to integrate these two areas, despite having contractual conditions that created from the outset an environment favourable to that integration.

In view of the structure that had been used by the Management Systems, in particular by the Q&S Management Systems, it could be seen that there was a possibility to make an advantageous total or partial integration of its components. The route followed to achieve this new objective will be expanded below.

3 Constraints detected that inhibited the integration of Q&S

After a first approach made with the winning bidder of the contract for the building of the structure in concrete, it was agreed to try to integrate the Q&S Management Systems. This agreement was made easier by the existence of the already mentioned contractual clauses and by the perception of all those involved of the possibility of optimising means and of increasing the efficiency of the performance of the Contractor.

Some constraints were however detected that deserve some thought and emphasis, in particular:

- the different stage of implementation and development of the Quality and Safety culture of the building Company;
- the compatibility of the contents of the Quality Plans and of the Safety and Health Plan, in particular due to the different moments and responsible entities in the preparation of these two documents;
- the absence of human resources capable of performing integrated duties in the implementation of Q&S systems;
- the systematic use of complex subcontracting and services chains;
- the difficulty in making compatible some procedures relating to inspection and tests, such as inspection and prevention procedures, in particular regarding the frequency of inspections;
- the absence of certification entities to certify the equipment manufactured prior to the integration in the Portuguese Law of the “Machines Directive”.

Because of these difficulties, a phased strategy was agreed with the Contractor for the integration of the two systems, which is described below.

4 Strategic approach of Q & S integration

To ensure a structured process of approach that efficiently guarantees the overcoming of the constraints detected, the Management of the Project proposed, and the Contractor accepted, the following phasing methodology to integrate the Quality and the Safety and Health Systems:

1st Phase

- Immediate integration of the Q&S Policy
- Creation of a Quality and Safety of the Project Committee.
- Preparation and implementation of a Quality and Safety Manual, including the following items:
  - Structure and control of the Q&S Manual;
  - Q&S Policy;
  - Q&S Management;
  - Duties and Responsibilities;
  - Implementation of the Q&S System;
  - Follow-up and Monitoring;
  - Review of the System.

2nd Phase

- Some Systems Procedures were identified which, due to their structure and contents, indicated a possible rapid integration, namely:
  - Control of Documents and Data;
  - Procurement;
  - Products Supplied by the Client;
  - Identification and traceability;
  - Process control;
  - Control of inspection, measuring and testing equipment;
  - State of inspection and Testing;
  - Control of Non-conforming Products;
  - Corrective and Preventive measures;
  - Control of Q&S records;
  - Q&S auditing;
  - Training.
- A training programme for employees of the Contractor and of the Supervision involved in the implementation of the above mentioned procedures was also created.

3rd Phase

The integration of the procedures of this 3rd phase was initiated with the Procedure relating to the *Control of Working Procedures* used in the works.

In this respect, it was agreed to prepare one single document including a brief description of each relevant working procedure, containing, at least, the following characteristics:

- Human means involved;
- Material means involved;
- Brief description of the activities involved, including the respective sequence;
- Identification of the aspects of each activity for inspection, testing and prevention verifications.

This situation has created a significant reduction in the bureaucratic burden of the Q&S Management Systems.

It was also decided to integrate, during this 3rd phase, some of the *Inspection and Prevention Procedures into the Inspection and Testing Procedures.*

As an example, we describe the approach made in respect of the prefabricated stands:

a) The placement and transportation of heavy prefabricated components (approximately 6000 to 8000 kg) is part of the so-called Special Risks, as defined in the "Construction Sites Directive" and in its integration into the Portuguese Law. In view of this, it became necessary to create the means of Q&S control that ensure the Safety of the workers and the compliance with the regulatory requirements.

b) The risk analysis carried out by the Coordination of Safety and Health identified as one of the possible causes for the fall of the reinforced concrete element, the failure of the fastening elements incorporated in the reinforced concrete slab. In view of the need for a control starting with the manufacturing phase in respect of Safety at Work, it was agreed to include items of verification of Safety at Work in the Inspection and Testing Procedures to be used during the manufacturing phase and the respective inclusion in the assembly Procedures of Inspection and Prevention. The fastening scheme of the component subject to integrated Q&S verification is shown in figure 1.

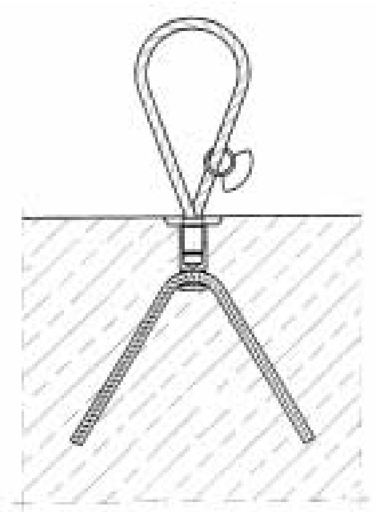


Figure 1 - Fastening point of the reinforced concrete component

With similar approaches, an integration of the applicable *Inspection, Testing and Prevention Procedures* of approximately 75% of the relevant activities of construction was achieved, among which the following are noted:

- the construction of pillars;
- the construction of girders of support of slabs;
- the construction of radial girders;

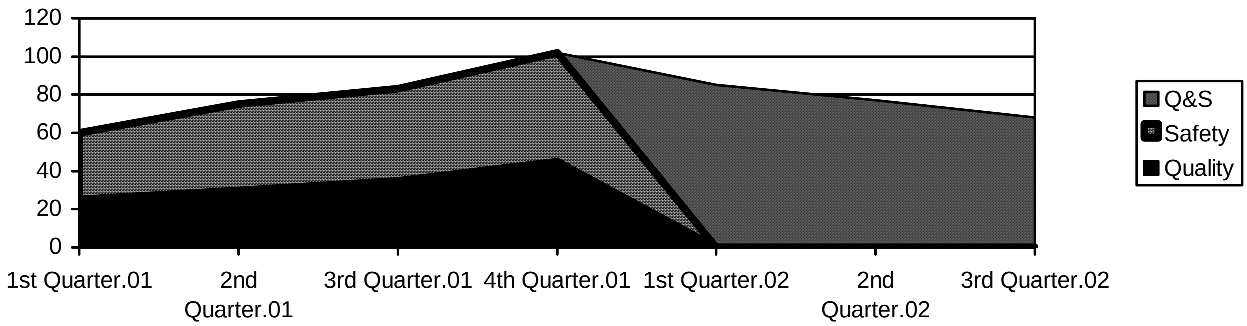
- the supply and assembly of alveolar slabs;
- the construction of poles of support of the roof;
- the supply and assembly of the roof.

In respect of integration, there were however some difficulties impossible to overcome in a totally satisfactory way, particularly in respect of:
- the control of equipment;
- Quality Plans and Safety and Health Plans.

5 The indicators and the performance of those involved before and after Q&S integration

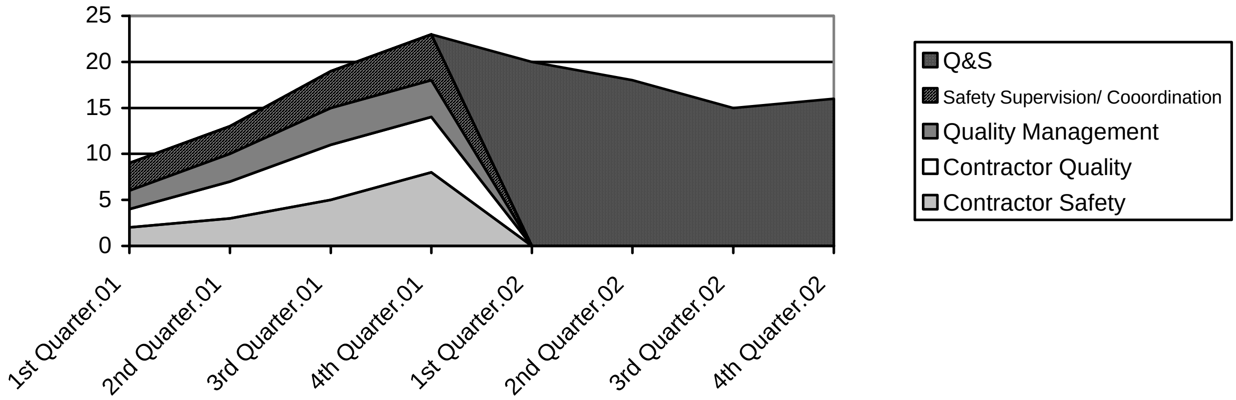
This item aims to introduce some indicators that show in a qualitative way the results obtained after the Q&S integration. For comparison of performance purposes, a time period of approximately two years was used, with only the last of these two years corresponding to the implementation stages of the Q&S integration. For that purpose, it is shown below, in a graph form, the following indicators:
- the number of non-conformities issued;
- the human resources directly employed in the works in respect of Q&S;
- the frequency rate of accidents at work;
- the severity rate of accidents at work.

a) Number of non-conformities issued in respect of Q&S



After the 4th Quarter of 2001, a decreasing trend can be seen in the total number of non-conformities issued, which was maintained until the end of 2002.

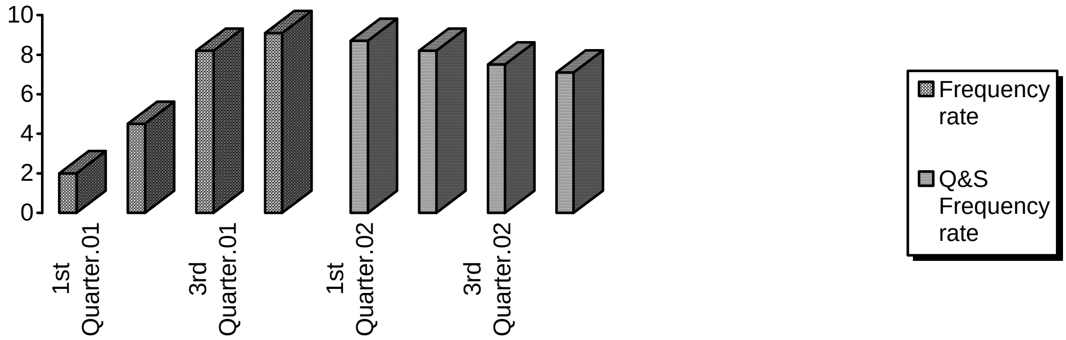
b) Human resources directly employed in the works in respect of Q&S



This figure on Q&S shows the total of human resources allocated to Quality and Safety Management, to Safety Coordination, to Safety Supervision and to the Contractor's Safety and Quality management/supervision.

After the integration of the systems, a reversal of the growing trend recorded during 2001) is clear, accompanied by the greater volume of work in progress. The slight increase recorded after the 3rd quarter of 2002 is due to the beginning of the construction of the cover of the stadium.

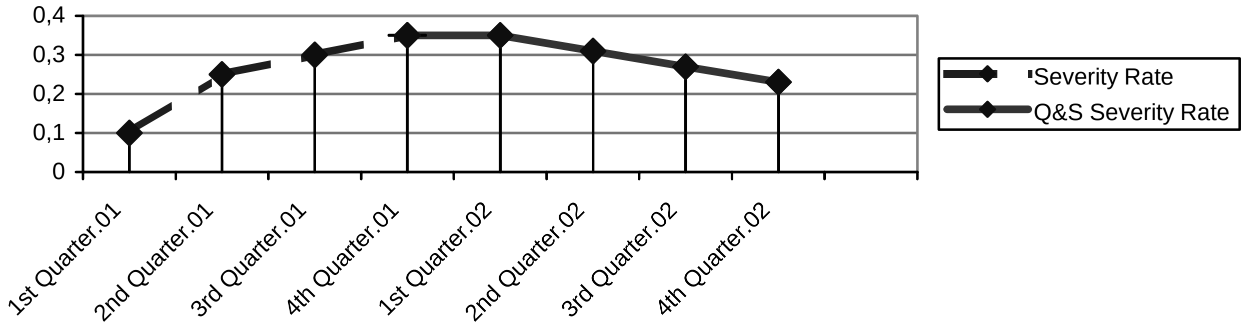
c) Frequency rate of accidents at work



Cumulative monthly figures are given, showing a decreasing trend of the frequency rate throughout 2002. This Frequency Rate is calculated on a monthly basis for the entire project, as follows.

$$FR = \frac{\text{No.accidents} \times 1\,000\,000}{\text{No. Men} \times \text{hours worked}}$$

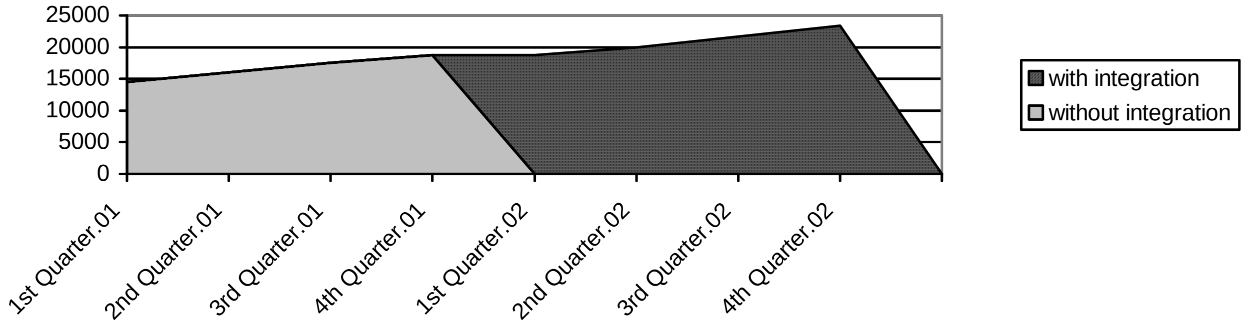
d) Severity rate of accidents at work



This figure shows cumulative rates that maintain the decreasing trend already shown by the other indicators. These figures are calculated on a monthly basis for the entire project, as follows:

$$\text{SR} = \frac{(\text{No. days lost} + \text{No. fatal Accid.} \times 7500) \times 1\,000}{\text{No. Men} \times \text{hours worked}}$$

e) Amount of invoicing/man/quarter(Euros)



The positive figures shown in the preceding graphs are reflected by increased productivity, as evidenced by the growing trend of the invoicing per man per quarter shown in this item.

6 Conclusions

This paper described the contractual requirements in respect of Quality and Safety and Health Management, taken into account in the procurement phase of the contract for the building of the new stadium for the Sporting Club of Portugal .

Despite being difficult to quantify, in a detailed way and unequivocally, the advantages of Q&S integration, the advantages of this integration were qualitatively shown by the indicators described in the paper.

The Q&S Management was made compatible through the Procedures included in the Quality Plan and in the Safety and Health Plan in order to optimise the human resources and the materials for its implementation.

The lack of training of human resources has justified a strong investment made in the area of training for the implementation of the Q&S Management Systems.

Management of Technology: approach to building construction quality planning

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Abstract

This paper proposes a quality management concept applied to building construction companies, stressing that quality does not only imply in meeting customer requirements, but also in the efficiency of its own production processes.

Under this approach, this study aims to debate the use of Project Quality Planning, quality management tool focused on the above-mentioned singularities, to integrate the relations among project players and the processes involved, to ensure the best quality and the evolution of Quality Management Systems (QMS).

Taking into account the involved diversity of products, players and processes in a construction project, this paper considers Management of Technology (MoT) introduction as an element that propitiates technological harmonization between players and processes, particularly in projects from Hospitality sector[1], which adopts rationalized or industrialized building construction processes.

In order to propose some guidelines, case studies methodology in the above-mentioned segment were carried out trying to identify the relations established between involved players, in which the Management of Technology could be put into an actual procedure.

Keywords

Quality management; construction technology

1 Introduction

We notice in the present social and economic situation, that technological development has affected the rules of international market and created such

[1] Market segment that involves Flat Services and Hotels

opportunities as problems to societies development (1). This landscape lets technology as an important agent of economic development and over all, as an instrument of strategy in the subsection of building construction[2] after parity with others sectors of the industry. So, the technology must be selected appropriately, developed and diffused in the sphere of organizations action, conducting them to a larger efficiency and efficacy.

Presenting this discussion in Brazilian building construction, we notice a considerable increase of the competitively of its enterprises and its market consciousness to a minimum standard of offered products qualities. This way, the subsection has been the scenery of a real ‘run’ in direction of quality and the insertion of new constructive technologies in its worksites and management processes. This can be analyzed as a strategy to reach competitively and make possible products with more generated value[3], under a process not only efficable but also efficient.

Therefore, due to intrinsic particularities, the segment still doesn’t presents sufficient results to desired evolution.

Taking this ‘strategies’- the implantation of Quality Management Systems (QMSs) in contractors and the way in which technology has been introduced in worksites – the main idea is focused: theorical exploration on the possibility of adding value to high performance building processes in the hospitality sector. Also taking as a premise, the integration between the QMS and the Management of Technology (MoT), based on harmonization of criterions that define hospitality sector project qualities.

Hospitality sector is adopted as focus in this study due to the characterization of design products created by its projects: buildings of a high performance. The ‘Hotel (seen as a building)' owns minimums demands, as shorter time of execution and delivery, that takes the necessity of higher grade of rationalization product; own demand of building performance in use with the aggregation of facilities and services in edifying (for example building automation and services performance is often being increased); and, equally, due to the utilization demand, the constant maintenance during its operation phase.

We believe that these are key points to the beginning of what we know about Projects Quality Management[4], an instrument to Quality Management Systems (QMSs) that makes possible its adjustment to particular interests of each project in building construction.

2 MoT contribution to QMSs and its projects

2.1 Projects and its function in building constructions segment

Considering its activities related to a transformation process, civil construction sector represents a group of activities of industrial configuration that is considerable in

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[2] A subsection in Brazilian Civil Construction.

[3] In the segment of Building Construction value generation into products means to enter in the matter of technical training and management enterprise practicing Constructive Processes that consider actualized techniques plus mechanization in the processes and lower job of workmanship (this its the more qualified) and over all conduced by a management without interference and the most optimized possible. We must think also in training of claims involved under an appropriate management to the internal context of the organization (contractor)

[4] To systems focused in the productive Building range (projects of new products) that delimit the estimate criterions of its quality.

Brazilian economy performance, in representing a considerable parcel of GDP (Gross Domestic Product) and has an important social function (2).

These activities, linked trough the project, configure a complex process, “a sequence of phases, generally with hierarchzing in the decision levels, great diffusion of responsibilities and low grade of integration between players” (3).

Thus, the production process (here) represented by the project shows na organizational structure divided in phases of distinct objects: conception, construction and use of the building; associating the fact that for each one of those phases exist a responsible factor for its conduction. It originates, then a series of activities that delimitate project life cycle, as a choice and acquisition of a land, its planning, introducing and commercializing in the market, beyond the definition and team coordination of the operational development (involving building processes: project and production) by the entrepreneur player.

Finally, we compare the project with a group of ‘enterprises’ working, parallel, in order to gain a common purpose: the building construction (Figure 1).

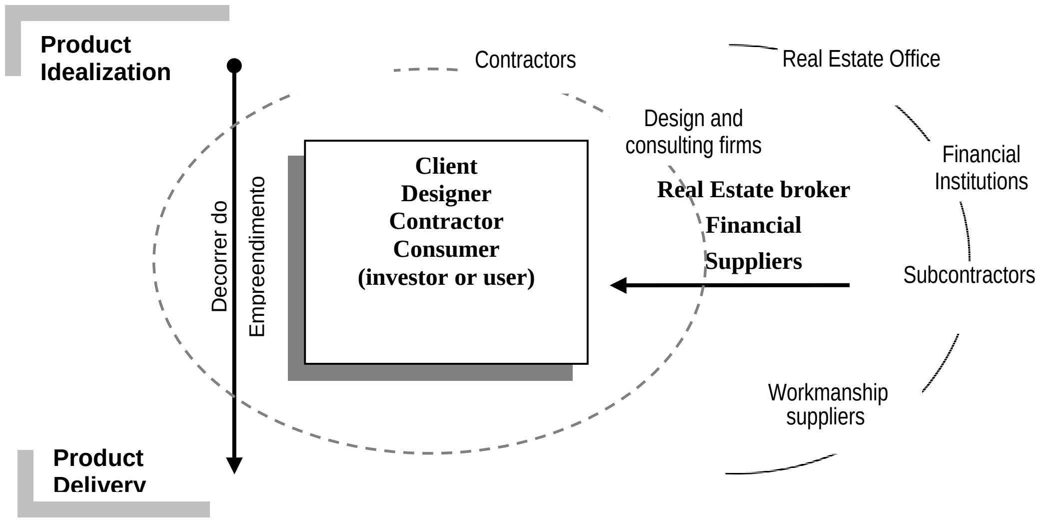

Figure 1 - Agents involved trough the development of the project.

We observe that the project isn’t exactly an independent organization - its existence depends on the initiative of an entrepreneur or enterprises, whose interests are represented in the projects. On the other hand, can be considered as independent production system, because its dynamical and own purposes: introducing, commercializing, and producing a product in the market. Here is being focused that projects, over all in the hospitality sector, involves an own management to each product introduced and for this reason, configures the ‘elementary cell’ (or elementary part) of the system delimitated by Building Construction, once that the activities of these segment circle around the projects. It can be seen as a sort of ‘project-enterprise’!

Understand the project as an elementary part of the segment BC take as bases the proposal of equalizing the Management of Technology (MoT) to Quality Management Systems (QMSs) ‘formatted’ to projects that introduces new products in the market.

Another particular characteristic of projects is the paradox ‘standardization *versus* specialization’ realized when the purposes were commented. In one aspect is the necessity of rationalizing the production and on the other exists the necessity of expressing a character of exclusivity in each project, in order to reach commercials purposes and client satisfaction. So, the continuity of works, which intend to reach total standardization of projects, becomes difficult due to its interests, requiring an adjustment between these variables.

This appreciation about projects can be understood as a fruit of its processes specialties in its production process and the technological and management diversity involved. We consider also, the fact that building construction segment (considering the contractors and incorporations) doesn't present a grade of technological uniform development, existing buildings produced by building processes since the most traditional to the most rationalized.

From the context approached before, we conclude the fact that in Brazil, building construction presents reduced productivity (90 to 100 Mh/m2) if compared to indexes of developed countries (30 to 35 Mh/m2) (4). Considering this, adaptations had been done since production models came in series industry[5]that are after alternatives that bring technological and organizational stages higher than production in the manufacturing character dominant in this segment.

QMSs also shows one of those instruments if considered as a management model inserted in an organization that makes possible, theoretically, products and services quality guarantee. Therefore, they are connected to building constructions environment and not to the 'project-enterprises', the elementary part in which activities are created in building construction segment.

2.2. From Quality Management s Systems to Projects Quality Plans

When we talk about Quality Management Systems (QMSs), the intended focus towards building construction is the one highlighted in GEHANI's work (1). When he quotes qualities awards such as the Baldrige National Quality Award in USA and the Deming Prize in Japan. Quality is understood as a product attribution, in an improving continuous process that allows its appropriate performance and that surpasses customer satisfaction, considering also process efficiency related to ways in which production occurs.

QMS represent a global management that delimits the qualitiy politics in organizations that interact in order to gain a common purpose: projects and enterprises process management systematization (5). They represent an instrument of management considering more efficiency and efficacy gave to an enterprise, resulting in higher quality of offered products and its client's satisfaction.

Standard ISO 9001 version to the year of 2000, for example, besides showing an effort to different aspects involved in organizations aim products characteristics conformity, focusing in topics that involve product procedure in its totality, allowing and creating then its various activities, allowing the transformation of its enters and exits (6).

Once that we notice the initial integration between the certification process to the real necessities of its enterprises and its projects, SJOHOLT (7) proposes an double to QMS: considering since the plan topics and the projects that take the supportable changes in enterprises, until the praise of the applications of these systems applications in projects life cycle parallel to the insertion in the ambit of each involved player.

Although this hostile character we have to know also that the QMS evolution in building construction must continue trough constant revision of standards, in the sense

[5] Lean production had been turned to lean construction, and the same happened with 'just in time system'.

of a higher overture to the specificity of its projects, 'cells' of the system shown by building construction.

For application of above-mentioned values to the project scale, it would be necessary the identification, analysis and formalization that are frequent in the respective operations. This action leads to the so called 'Quality Plan', tool of QMS that allows agents interventions optimization and structures integrated actions within organization QMS scope, resulting in its fit to the project specification and quality assurance of the products to be generated. (8).

The statement given by Engineer Ércio Tomaz reinforces the idea that "*investing in the quality of management, procedures, documents, is not bad, since it is seen as a way of organization. The problem happens when it does not aggregate technical knowledge. For example, today it is very common that large corporations manage a construction like an independent branch, with separate management, separate resources and separate management of the techniques. It is necessary to correct what did not work out in the construction to avoid its repetition in other buildings*" (9).

It means that it is not enough to implement in the company a QMS which guarantees the quality of the final product, if there is no incorporation of technical-technological values in its respective management and projects.

2.3. Technology and Innovation

To make the insertion of Technology feasible in project practices it is necessary a systematic view over its plan and operation. So, as a consequence, it is necessary to make use of Management of Technology (MoT) integrated with Projects Quality Plans.

The understanding about the implementation of MoT in the segment of buildings designed for the hospitality sector[6] implies in the distinction and use of expressions as 'technical' and 'technology' several times used in a different way from the actual sense.

Technical is understood as a set of practical rules to determine certain objectives involving professional skills to make some things and skills to be transmitted orally, for example the use of hands, instruments, tools and machines (10). It means the act of knowing how to do

On the other hand, Technology means "*the study and knowledge of the technical operations or technical. It involves the systematic study of instruments, tools and machines used in the various branches, gesturtes, work time and costs of materials and energy consumed*" (10). It implies in the use of methods derived from natural sciences representing the evolution in accordance with changes, which occur in society's evolution.

By transporting this rationale to a program of system organization it means that the Technology makes use of means and knowledge to enable better quality and low cost products. So, technology may generate both: a major productivity and product quality as well as lead to the discovery of a new production technique or a more efficient management.

This idea is associated with the eight fundamental points of Technology: (1) "*products, operational process, intellectual property, information process, promise (of quality and trust), the qualification of people, project and plan, pioneering strategy to attract financial gains*". Ribault et al (11) say: "*Technology represents a complex set of knowledge, means and know-how organized towards production*". Under these

[6] High Performance hotel Buildings.

terms, the adoption of 'Technology' concept applies not only to the segment of building industry but also to the Technology of products (materials, components and construction systems) and construction processes (building technology), and also to the project management technology, including the interaction between all agents and processes involved.

2.4 Management Of Technology And Innovation

Essentially, Management of Technology (MoT) is described as a process of development, choices and diffusion of Technology within the scope of a process or a project (11). This represents the configuration of the system policies, management, and procedures that outline the strategy and operation, which will enable the achievement of project purposes.

MoT represents not only the capacity to allocate resources to the Research and Development (R&D) but also the commitment of these resources to other complementary capacities inherent to the chain of an organization's technical values (1), such as project plan, the carrying out of building construction and its respective maintenance as well as the integration among activities involved in its life cycle.

Due to this reason, MoT implies gains of competence and competition during its life cycle. These gains occur, according to the logical of Porter (12) by costs domination, products differentiation or in the concentration of a specific market or by the necessity of working with strategies in project environment. After all without a strategy there is no plan and without a plan the uncertainties predominate, wrong options may be taken and there is no learning derived from the experience.

The limits of understanding over MoT universe are established considering policies to choose, define, develop, implement and spread rationalized constructive technology within projects scope. MoT main key points to be identified along projects life cycle must be based on the phases of motivation for the adoption of Technology and innovation, its selection, R&D, implementation and operation, diffusion and learning for re-innovation (13).

Motivation involves "detecting signals in the environment about potential for a change, that could be the result of a competitor action or from the interplay of several forces, some coming from the need for change pulling through innovation and others from the push which comes from new opportunities" (13).

It is part of this stage the identification of key factors which lead to companies involved in the project to an innovation: core competencies involved in the process and in the tasks to be done.

Research and Development (R&D) involves the combination of new and existent knowledge, available inside and outside of the organizations involved, which are oriented to find problems solutions that arise along building construction. Ways out that characterize the product at this phase of MoT process are the changes that advance to a higher stage towards a more efficient stage of a certain process of the project.

The main point at this stage is the innovation that comes from a collection of ideas to a concrete reality. In this way we can outline which resources are to be applied, search for more information, inside and outside of the organization or project (benchmarking) and finally determine the detailed activity of innovation development or its adaptation. This process must be understood as a concept of routine "*in which the organization develops a particular way of behavior that sets the manner of doing things and reflects the culture of the organization*". (14)

Implementation, the center Mot and innovation processes has as ways in the clear strategic concept, and technological innovation introduction into the project; while its ways out are the developed innovation associated with the domestic and external markets (13). So, the procedures are settled, the human resources are capacitated and the suppliers begin to be informed about the changes that were implemented.

The technological innovation was developed and implemented in the organizations and as a result there arises an environment propitious to the respective operation and diffusion and it becomes inherent to organizations daily activity.

The **learning and re-innovation** represent the way out from this MoT process. The creation of new motivation to define again new projects life cycle. If the product or project fails, we obtain valuable information regarding what has to be changed in a next time.

It is true that it is not easy to manage such a complex and uncertain undertaking, moreover when it is applied to building processes projects. TIDD et al (13) explain that it is a delicate matter to develop and to refine a new knowledge as the adaptation and application of this knowledge to new products and procedures, to convince the directors of the companies involved in resources application, to accept long term use, etc. These are difficult issues, but possible.

'Innovation' is a process, not a singular event; consequently it has to be managed in an appropriate way: "*the influences over this process can be handled to affect the ways out, that is, it can be managed*" (13). Another critical point emerges from the research. It is that the innovation needs to be managed in an integrated form, considering all the agents involved in the projects and not only manage or develop the skills separately in some of the organizations involved in a building project.

About the handling of this integration, we believe that the Project Quality Plan is the tool that balances projects requirements and interests, relative to the respective QMS and MoT of agents involved. Therefore, when thinking about integration it is necessary to consider the integration between QMS and MoT.

3 Integration

The discussion about the integration between QMS and MoT begins when it is admitted that integration exists in the daily activity of organizations. It is enough to identify the links existing between a QMS already formalized and a MoT practiced informally by the contractor and the incorporator and even applied to projects.

These links occur under the form of two vectors: in the first (1) QMS are conditioning the MoT and the second (2) represents the influence of MoT over QMS.

It is clear that the vector (1) predominates over the productive structure of a company, as the QMS formalized in the organization (not always certified) is able to exercise more influence over the MoT practice. Illustration of these vectors can be listed:

1. QMS interacting in MoT – when the quality requirements or procedures are settled in the QMS they limit or determine which technology will be used. Delivery terms are an example: if QMS requirements establish that these cannot be postponed for more than two months from the clause established in contract, production management, procedures and processes for building construction must be efficient enough to enable the delivery within the delivery term. The requirement 'delivery term' will choose,

therefore, the production technology that will ensure a shorter construction period, either through the use of pre-existing components or through an innovative system of production management.

2. MoT interacting with QMS – Considering the same example, the requirement ‘terms’. If one criterion adopted for the choice of technology is based in the search for shorter terms, the technologies used will be efficient and effective to ensure the term, with implication in a major control of the procedure and consequent quality of final products.

   Another criterion for the choice is the technological risk. Once accepted the risks (either relative to costs, terms or technique application), the implementation and choice of technology in projects building processes may result in a loss of quality or in the default of a quality requirement.

It is pointed out also that the vectors arise as a consequence of the reality of the companies involved in the project. The PQP arises just as an element, which fits the interests of these various agents.

But why contribute and integrate?

As it can be observed the link exists in an interactive form. It is necessary to have sound criteria to identify these links in order to have a balance in this interaction and so establish the efficiency and productivity derived from the procedures and technologies applied[7]. These balanced with the efficiency of same (always associated with the QMS but not necessarily with the efficiency of the operational procedure). Finally it is shown that both systems interact between themselves, but are not thought under a synergetic way. The example is just the vectors of interaction (1) and (2) coexisting without balance if compared to the action of one with the other.

It is necessary, also, to practice MoT and QMS in accordance with the demands from the market (proprietors and users of the building) and with the necessity of surmounting ‘companies–project’ productive capacity.

4 Case studies development framework

Considering that hospitality sector projects aren’t conduced by only one organization or player, but for a pool of enterprises; we propose the case studies framework, which translates the discussed elements.

The goal is showing the practical results from interaction between involved players in hospitality sector projects, considering also technological relationships occurred into these processes. We understand also that these results can be analyzed as results from application of the Quality Planning tool, which can improve those interactions.

This way, practical results of this work can be translated in good practices for Projects Quality Planning in Hospitality Sector.

Once we intend to cover the whole process of projects in Hospitality Sector, we understand that the beginning should starts from the end. It means that, we must attempt to the results gained during the operation phase of the project (the building and its uses), trough Post-Occupancy Evaluations (POEs), which supplies vital information – related to the facility of maintenance and acceptation of users – to the retro-alimentation of future projects.

[7] Purposes of the MoT

These data are the links that able an efficient tool for the initial approach case studies, once that they concern the practical results from phases of conception and implementation (construction) of projects in hospitality sector.

Figure 2 establishes a model to guide this work, considering projects life cycle.

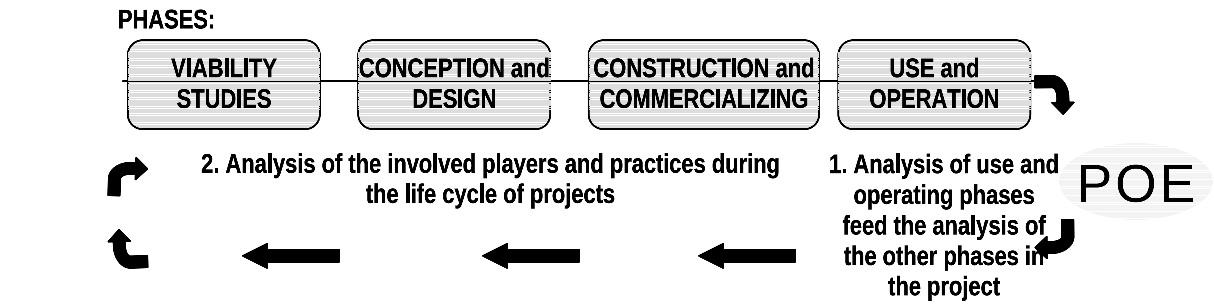

Figure 2 - 'Proto-model' to the analysis of the study cases. The model considers that 'the beginning comes from end'. The results from use and operation phase bases the characterization of the life cycle of a project, considering also the practices of MoT and relations that comes from application of a Project Quality Planning.

In a second stage, we must initiate the identification of practices of QMS and MoT of players that conduces and operate the technology production in buildings, the entrepreneur and the constructor without disrespecting the other factors involved in it.

Once dominating the information related to the practical application of conception and construction solutions, there are established an accurate environment for detailed characterization of the project, which is related to: the factors and players involved, the building process, the quality management system.

These all leads with better conditions to formulate (or collaborate) models of project Quality Plans that regard this integration. See Figure 3.

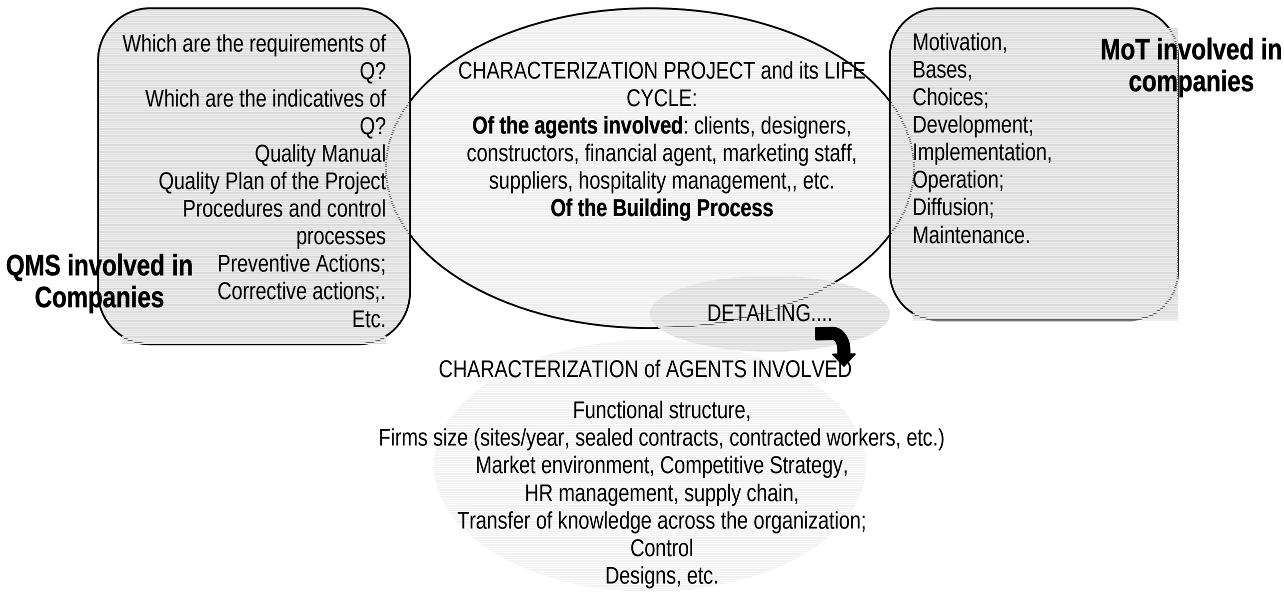

Figure 3 - Matrix to the detailed survey datum in the case studies.

5 Conclusion

Considering QMS to MoT integration purpose practiced along hospitalities project life cycle through Projects Quality Plans, the discussion raised around MoT still considers the environment of serial industry. It is necessary an analysis which leads this discussion to the issue building construction, considering high performance buildings in hospitality sector, and matters that meet the specific requirements of each project combining involved agents interests. In connection with integration, preparation of spread sheets for case study and its analysis shows how extensive is the research, confirming the thesis that integration comes to frame an organizational and productive structure for projects. The intention is to make clearer the limits of agents involved roles, its respective interaction and the consequent conversion of their joint efforts towards the obtainment of an efficient building production.

Just to finalize, a critical point arises from the study, that is, project MoT and not only the management of some organizations involved in it.

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Analysis of the development and use of design for production in building construction – contribution for the design management

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Abstract

The adoption of ISO 9000 standards and other quality certification systems are now a reality in the Brazilian building construction and a lot of companies have obtained the certification of their quality management systems.

The investment made by those companies for the standardization of their processes, developing very complex quality management systems, is notorious. Architectural design firms, whose adhesion to the quality movement is more recent and still restricted, have followed the same tendency as the contractors. Even so, the integration of contractors' and designers' activities is neither simple nor evident, which is reflected in individual results and in those of the project.

Thus, although many actions have already been implemented for the improvement of design process, aspects observed in the site – such as execution difficulties, incompatibility of designs due to lack of integration among designers or among designers and other teams – are still hindrances for obtaining results with regard to the quality field.

The employment of design for production has been pointed out, in several surveys, as a mechanism of great potential for overcoming those barriers; even so, the achievement of this potential is questioned.

The aim of this paper is to analyse the development and use of design for production into the day-to-day of building sites, pointing out their contribution for conducting construction activities and for the integration between design and execution phases. The paper presents the benefits, difficulties and tendencies in the employment of this kind of design that was found in one case study, involving a qualified company in Sao Paulo City, stressing their importance for design process management and for the project success.

Keywords

Design for production; design process management; site management

1 Introduction

Building companies, due to the implementation of QMS (Quality Management System), underwent an “organizational adjustment”, structuring themselves for the changes conceived in the building market. Reis (1998) affirms that “from the moment the implementation of QMS brought a better organization and a better understanding of the work in the organization internal sectors, attentions were focused on the design, once it is the original link of the whole productive chain, whose solutions reverberate over all the stages of the project and affect several interventions that take part in the building production process”. From the points emphasized by the author, concerning the design stage, it is clear the increase of demands for design related to the needs of production in the work and which bring, in contents, rationality and economy to the construction.

The demand for elaboration of design for production aiming at the definition and the detail of certain subsystems of the building has increased and has enlarged the possibility of improving the conception and the development of the design, as well as the integration between designers and contractors (Zegarra et al, 1999). Many authors, such as Souza (1996), have emphasized the main role of design for production in solving questions that involve the adoption of a certain constructive technology, also in terms of alternatives for specification and details of the product itself, along the design elaboration, by inserting conditional factors of optimisation and buildability, to eventually present a definite production process, allowing its control and ensuring the project the desired quality.

Specialized companies are already developing the concept of design for production of several subsystems, specially masonry design. However, because of this changing process, there is concern about the correct use of these designs, so that they do not lose their original purpose, which is to meet the needs of production. It is feared that design for production becomes one more design subject and presents the same problems faced so far in the process. That is why the building company must be prepared, from a management point of view, so that the production project insertion is adequate to be properly used.

The case study presented in this paper allows to verify the main aspects related to the management of the project process in-house and to the management of the work studied itself, which directly interferes in the use of the design for production.

The benefits and the difficulties in the use of these designs will be pointed out under the builder- staff- in-the-work view. It is important to emphasize that this paper is part of the author’s research, in which other companies presenting different characteristics were also studied, which made possible to outline the present reality about the use of the design for production.

2 Case Study

2.1 Methodology proposed

The methodology proposed consists in studying the several project players roles as well as the use of the design for production (DP) in building construction. Having the knowledge of the relation existing between the several DP development process players, it is necessary to define each one’s attribution in the process and to identify the existing difficulties in its use, where they may occur, and how to solve them. The following project players were thereby studied:

a) Building Company:

AIM: identifying and characterizing the design activities flow in-house and their respective players, verifying:

- The relation between the building company (design staff) x external designers, design manager x internal designers; others;
- The documentation concerning the design;
- Scope of the design for production under the building company point of view;
- The stage of decision-making concerning the DP; who is responsible for making the decisions.

METHOD USED: interviews with several process players and meetings (verification of procedures and of available documentation).

b) Design for production firm:

AIM: to verify the relation: designers x building companies; designers x site teams; designers x suppliers; to understand the DP development under the designer point of view; verifying the designer's DP scope.

METHOD USED: Interview with the designer related to the contractor. Verifying procedures, available documentation and attendance in meetings, when necessary.

c) Execution staffs (work coordinators; site engineers, subcontractors, manpower).

AIM: To analyse the work under some aspects: presentation (standardization and intelligible language), scope, detail level, ease in building up, production staff satisfaction and acceptance level, modifications occurred (why); to verify the relation: execution staffs (ES) x designers and ES x design firm manager.

METHOD USED: visit of a building company work at the design stage.

2.2 Global Analysis

Global analysis is based on some aspects especially concerning the management of the project process in the building company and management of the work. It is important to emphasize that each work will be analysed, regarding the points related to each of the players. The aspects studied are:

- Design process stage in which the design for production hiring takes place;
- Design for production feed-back for the building company design department.
- Presentation of the design for production in the site by the designer.
- Manpower training;
- Supply, storage and transportation of materials in the site.

2.3 Profile of the company studied

The company studied has acted in the real estate development and construction of buildings since 1977, having its first work concluded in 1979. It has approximately 300 employees and produces, on an average, from six to eight building projects annually, which characterizes it as a large firm. Acting essentially in the private market, it is characterized by building high- and medium-standard residential buildings, commercial and industrial buildings, as well as medium standard blocks of houses, adopting constructive technologies such as reinforced concrete frames with ceramic masonry walls of external rendering and internal gypsum tile (except for the 1st and the last storeys).

The building company is introducing a quality management system (PBQP-H), being at present at level C i.e. the second level in this Program. The company is in process of elaborating its procedures and handbooks, and may reach certification level A by the end of 2003. It is noticed that the company has been adopting the principles of quality in its process for some time, which is observed by its directors as well. According to the company design co-ordinator, one of the reasons that led the company to seek the certification was exactly the demand for banks granting lending, which is only allowed with quality certification. According to the company development manager, the main aspect resulting from the implementation of a Quality Management System "is the standardization of all the procedures in the works, integrated with all the sectors". The company has been reaching satisfactory results with QMS because, besides improving the quality and the services, the staff feels committed to the success of the system.

Among several changes occurred with the implementation of QMS, quoted by the development manager, the possibility for the design to become one of the main tools to reach quality of the several work services is pointed out, thereby stressing its importance.

It is important to emphasize that before the implementation of QMS, , since 1994, the company has been developing an optimisation program, seeking financial, human and material resources, focusing on standardizing the production process, minimizing wastes. This program is based on four main ideas:

a) Elaboration of design for production;

b) Production technology, acting on constructive methods and techniques, as well as on materials, components, equipments and tools;

c) Organization of the production (planning, production control and organization of the building site);

d) Production management, aiming at contracts of services and administration of inputs in the building site.

This program offers the company not only sustainability to promote its technological development, but also a proper environment for implementing QMS. It is noticed that the company considers it important to use design for production for optimising production.

According to the development manager, the company "always considered the design as one of the important factors to attain quality in services", even before the implementation of QMS. The company counts on a design department represented by one design manager, two design coordinators, one designer and one trainee. The whole department is subordinated to the Technical board. Coordinators are represented by two architects whose attribution is to integrate all the designs through meetings with the designers and with the engineers responsible for the production in the site. The company acts during all the elaboration of the design and during the site works execution.

In the company design process, both the new business board linked to incorporation, and the company president, make the decisions concerning the release of a project, outlining the product as a whole. The product is defined based on a marketing research concerning typology and a series of other factors directly related to the design itself, economical viability, costs, etc. Once the profile of the new project is defined, the architect is responsible for giving the guidelines concerning the definition of the number of storeys, type of building, including preliminary studies. Although designers of other specialties do not take part at the design stage, they give consultancy, advising the architect in the definition of parameters that help the elaboration of the design and other subsequent factors. This relationship is the result of lasting partnerships between the company and the designers of several specialties.

This design, still incipient, is sent to the company design department. The design manager sends it on to designers of some specialties, such as frames, exhaustion, hydraulics; a pre-analysis of the project is done before being sent to the municipality organisms. All the information is thereby harmonized for the design to be approved by the competent organisms. After the design approval, which originates the legal design, other designers mentioned before will be formally contracted and they will start to develop several ante designs. According to the design coordinator, three meetings for "fine-tuning" are usually held, not simultaneously, but with each project specialty separately, when adjustments are necessary. These meetings normally occur firstly when designers are hired, after the end of scheme design elaboration and after definite design conclusion. The design proceeds gradually, passing through pre-definite and, definite design, up to the final detailing.

The company does not develop designs in-house, thereby hiring all the necessary designs to the construction of the project. Besides usual designs such as architecture, structures, foundation, electric and hydraulic systems, landscape gardening, decoration, air-conditioning, among others, the company also contract designers to formwork, partitions and façades.

The first design for production used by the company was the partition design for production, seven years ago, when the company started to invest in technological development, culminating at present in the use of designs from other subsystems in the building. Before their use, the decisions concerning the work were made by the execution staff, bringing uncertainties to the process. According to the coordinator, "DP helped decrease these uncertainties". Although the company uses other modalities of design for production, this paper will analyse the partition project only, due to its importance and availability for studying it in the company.

2.4 Scope of the masonry design studied

The masonry design presented by the company is composed of the following elements:

- Location plan of partition walls, paper format A0 and on scale 1:25;
- Marking plan of 1st storey tiers, paper format A0 and on scale 1:25;
- Distribution plan of storey electric fixture, paper format A0 and on scale 1:25;
- Perforation plan of storey electric fixture, paper format Al and on scale 1:25;
- Rising plans of partition walls, paper format A4 and on scale 1:25;
- Floor plan, paper format Al and on scale 1:50.

2.5 Analysis of the studied building site

The building, whose construction started in November 2001 and which ends in the foreseen date of December 2003, presents two basements, one ground storey, one mezzanine and twenty storeys with six apartments on each floor, each apartment having 60 m2 in area. The apartments are composed of one living room and one dining room, one terrace, two bedrooms, two bathrooms, kitchen and laundry area.

The building is built of reinforced concrete frame of fcK 25 MPa, presenting slab thickness from 12 to 14 cm under foundation of open-air-large-diameter tubes. Partition masonry is made of ceramic blocks of internal gypsum lining, applied over the block (except for the 1st and the last storeys), and of external rendering and painting. At the time of the case study, the work was at the partition masonry execution stage of the 13th storey.

The organizational structure of the building site is composed of one site engineer responsible (who has been working in the company studied for 3.5 years and who has a 10-year-building-experience in other companies, especially industrial buildings), two full-time trainees, one marker (administrative), one carpentry foreman, one mason foreman and one warehouse assistant. All of them are the company own manpower. Most of the remaining manpower is hired from specialized service companies.

According to the site engineer responsible for the construction of the building, there were no delay in delivering the partition design, in comparison with the beginning of the service to be executed. After being analysed and approved, the design for production of partitions was sent out to the site by the design department. Before starting its execution, a designer representative was at the site to explain the design to the execution staff.

After the execution of the 1st storey, which works like the prototype used in industry, the main problems are identified, such as the solutions adopted concerning *buildability* and some mistakes made in the design, usually concerning modulation or adjustment to some precast piece used. These problems were noted down in the occurrence notebook and passed on to the designer who previously visited the jobsite (at the engineer's request) to analyse and identify the problems related, and who reviewed the design of the following storeys. The engineer reported that he had not taken direct part in the design elaboration stage, which only took place in the execution of the 1st storey.

The development manager emphasizes that the implementation of the design for production on the 1st storey is done little by little, by verifying if the execution staff is getting familiarized to the design. Thereby, first the masonry location plan is verified before its execution and the main difficulties are remarked. Second, the marking plan is checked and so on, until the execution of the 1st storey is complete. Because of this process, the execution of the 1st storey usually takes longer than the other subsequent storeys, which allows the manpower to get used to the masonry design. Only at this moment is the designer asked to visit the site because, according to the development manager, the designer's visit is onerous.

The masonry design for production analysed shows a great deal of pre-casted pieces (about nineteen) and blocks of several thicknesses and lengths to be compatible with the horizontal and vertical modulation of the design, according to specification of the elevation notebook. To see to the demand of the pre-casted pieces of the design, a manufacturing station was installed on the basement. To manufacture these pieces, the following materials are necessary: metallic moulds and concrete made of one 18-liter can of cement, 1 ½ 18-liter can of sand and 1 can of crushed stone. According to the worker responsible for manufacturing these pieces, the amount of water used was enough to produce a mixture of granular and dry aspect, which can be easily compacted. Compaction is done using a hammer over a thin piece of wood directly over the piece.

A non-qualified worker of the company is responsible for manufacturing these pieces in the manufacturing station. To ensure that, the trainee of engineer gave him initial instructions about the manufacture of these pieces, instructions about the composition and the amount of each piece per storey. About 50 pieces are made daily, depending on the type, but this amount may decrease to 24 in case of more complicated pieces. The responsible reported that the pieces are used 24 hours after manufacturing, because they are widely used. No specific control of these pieces was verified in the manufacturing station. According to one of the contractors responsible for masonry execution, the contractors themselves usually request the manufacturing of certain pieces in the manufacturing station and there were moments when work had to be stopped, due to the lack of certain pieces.

The blocks furnished are stored on the ground floor over pallets, forming 10 piles on the whole, maintaining their physical integrity. The identification of the blocks was verified according to their thickness and length, in an easy-access place in order to transport them to the crane. Pallet carrier cars and a crane transport the blocks from the stock place until the execution storey, through horizontal and vertical transportation, respectively. Blocks are located according to the execution staffs localization.

The materials used to manufacture mortar are transported to this floor in sacks containing the predetermined amounts, according to specification of the composition by the development manager. Cement is packed on the ground floor in amounts of 8 kg to masonry. Sand is packed on the basement in amounts of 33 kg and lime is furnished in sacks of 5,5 kg. These materials go to the basement where mortar is manufactured at the rate of two 33-kg sacks of sand, a sack of lime (according to supplier standard) and an 8-kg sack of cement . According to the engineer responsible for the construction of the building, there were no delays in delivering ceramic blocks that could endanger the masonry execution process. One of the contractors related that the lack of a certain block did not endanger masonry, but there were moments when it was necessary to change the specification of the design concerning the thickness of the wall, due to delays in delivering blocks. For example, the design specified the need of blocks for 14-cm walls, but in the site there were only blocks of 11,5 cm and these were used instead of the specified ones.

An agreement was verified between the company and the suppliers, the result of a lasting partnership, according to the development manager. One of the attributions of the company development department is to search for suppliers whose products can meet the requirements of the standards of quality and performance expected and that can ensure the continuance of supplies. The development manager reported that, when the rationalization program was introduced in the company, in 1994, they were initially searching for improving the aesthetic aspect of masonry. Thereby, many problems involving cracks and fissures were found, which encouraged the company to analyse the performance of the masonry and the criteria to be adopted in the specification of materials, in order to execute them properly. Thereby, there were concerns not only about aesthetic aspects, but also about the performance of the materials used and final masonry. Several essays with blocks and mortar from the main suppliers were performed in order to establish partnerships with those who could supply products that could ensure the performance of masonry. The development manger said that the resistance to the compression of the partition blocks used reaches 8,5 MPa. Specific pattern values register a least of 2,5 MPa, but according to him, this value is not enough to ensure a satisfactory performance of masonry.

The manpower used for executing masonry in the work studied is subcontracted from two different companies. The contractor company E1 (CC1), has been acting in the building market for four years, rendering services to the company such as masonry, revetment and services in general. The staff is composed of 25 workmen, six of them are masons and two of them are workers who are subcontracted. There was no specific training of the execution staff by specialized companies. The company itself offered this training, through the reading of the company masonry execution procedures by the trainee, who explains the main points, and through orientation during the execution of masonry on the 1st storey. The contractor reported there was initial difficulty in the use of design for production because of the staff little experience with masonry, which occurred because he dispensed with the previous staff (which was used to the design), due to lack of work in the company during a period of six months. The main difficulties concerning manpower, according to the contractor, were: initial resistance concerning the use of masonry design, great amount of blocks and pre-casted used, which disturbed the productivity in the execution of the first three storeys, difficulties to read the design for not being used to it, and disqualified manpower. The contractor emphasizes that masonry design considerably improved the final quality, the esthetical aspect as well as helping decrease pathologies such as fissures, once it is designed to reach better performances. He reported that cleanness in the storey improved a lot, because it is necessary to let it free for the installation of masonry. He emphasized that the design demands manpower to be much more qualified than in the past, because now manpower needs to execute masonry as well as interpret the design. According to him, “anyone in the past could build a wall; all you had to do was to put mortar and blocks respectively, and in the end, according to the space left, you broke the blocks, and there was not the use of screens”. “When manpower is correctly trained, the design simplifies the execution of masonry”.

The contractor company E2 (CC2) has been acting in the building market in Sao Paulo since 1995. It began executing other services in the company. It has a staff composed of 28 employees, eight of them are masons and three of them are mason trainees. This is its first masonry work executed for the company. The contractor reported that it has already executed masonry without design for production in other companies and he observed a considerable difference in its final quality. He added that the use of design does not allow improvising constantly and it makes clear which must be its final aspect, besides making the execution of masonry stage by stage easy, through location and marking plans and through the rising plans.

According to the engineer, to the contractors and to the manpower itself, some problems were pointed out, involving management of the work and insertion of the masonry design for production:

- One pre-casted piece specified in the design could not be adjusted to the modulation of masonry, which establishes its cut along the execution. After the execution of masonry on the 1st storey, there was a change in the design so that the angle of the piece could be adjusted to the concerning wall;
- Manpower was not properly executing the distribution of joints of the horizontal modulation, which caused the blocks to break in the final adjustment of the wall. The design foresees some adjustment joints which must be observed during execution;
- The blocks in the connection of walls with columns were not being properly compressed, causing adherence between interfaces. This fact was observed by the engineer, who pointed out a failure in execution: the blocks of the middle of the tier were being adjusted prior to the blocks of the edge. This fact occurs,

according to him, due to execution staff's inexperience and unfamiliarity with procedures and with the company system;

- Difficulty in mooring blocks in the connection of walls;
- Some walls presented problems in plumbing, causing the collapse of a wall;
- Some masons had difficulty in keeping the thickness specified in the design to fix masonry to the beam or to the slab (2 to 3 cm), causing the withdrawal of the last tier to put another type of block, differing from what had been foreseen;
- Dirt on the execution floor. The company demands cleanness in the execution of its works;
- Some types of blocks were substituted in the adjustment by others that were not specific to a certain tier due to its lack in the building site, at the moment of the execution. This fact occurred so that the work process was not damaged. According to the engineer, there was little occurrence of this fact;
- One wall had a fissure in the connection with the column, in all the floors. This fact was reported to the structural designer, to the development manager and to the masonry designer, who held several meetings to discuss the problem. According to the development manager, it is believed that it may be a problem of deformation of the slab, (confirmed by the designer of structures himself) whose dimensioning was made difficult by the architectonic party option in which the slab of the storey presented a very marked unevenness;
- One wall was identified consisting of location and marking plans, however it was not noted down on the rising plans and it had to be adapted in the jobsite;
- The unevenness verified in the storey, according to the architectonic option and the definition of only one longitudinal axle, made the installation of masonry difficult in the places where this unevenness jutted out;
- Workers reported that some little adaptations were made in some walls, such as: installation of compensating blocks, when it was not specified in the project, so that the joint would not present a very prominent thickness; breakage of blocks in the last tier to promote the passage of electrical circuits (the project does not foresee it);
- The wall presented rips after the passage of hydraulic pipelines. The masonry project does not foresee the interference of hydraulics in the wall. According to the development manager, this is a problem to be solved. At least, optimisation is done ripping the wall with an electric cutter.

It is emphasized that many of the problems concerning the execution of masonry, especially concerning manpower, were minimized from the execution of the third storey on, when workers were familiarized with the design.

According to the site engineer, technical meetings with the board are held monthly to discuss problems about the work studied, main difficulties and solutions adopted to solve these problems. Besides the meetings, the engineer provides a written report of non-conformities, when the work is being concluded, which is sent out to the development manager and to the project department.

Concerning his opinion, the main benefits obtained with the use of design for production are: better quality in execution, improvement in quality control, improvement in productivity when the staff is properly qualified and trained, optimisation of materials and decreased waste.

3 Conclusion

The use of design for production for several elements of buildings is a reality incorporated in the state of Sao Paulo. The benefits of their use have been verified, pointed out especially by the execution teams, emphasizing the decrease in uncertainties and in decisions made in the building site, increase in productivity and in quality of the service executed.

Building companies must be prepared from the management of its suppliers as a whole, whatever it involves manpower, construction materials or design, so that the insertion of the design for production takes place properly, attaining the purpose to which it was conceived: simplifying the production process.

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Professional consulting firms as learning organisations in the Tanzania construction industry: a case of a developing country

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Abstract

The specific nature of construction projects makes each project a learning opportunity for professional consultants. Of interest is whether such firms perceive themselves as learning organisations and hence facilitate mechanism for being so. As learning is not spontaneous, concerted efforts need to be pursued for organisations to learn. This article has looked into how professional consulting firms in the Tanzania construction industry learn. Data collected and analysed through a 5-stage knowledge transfer model indicated existence of shortcomings that bar organisational learning ranging from the modality of inter-firm linkages, tools used for performance review, biases towards single-loop learning, use of individuals as key organisational repositories to the mode of information retrieval.

Keywords

Construction projects; consulting firms; organisational learning

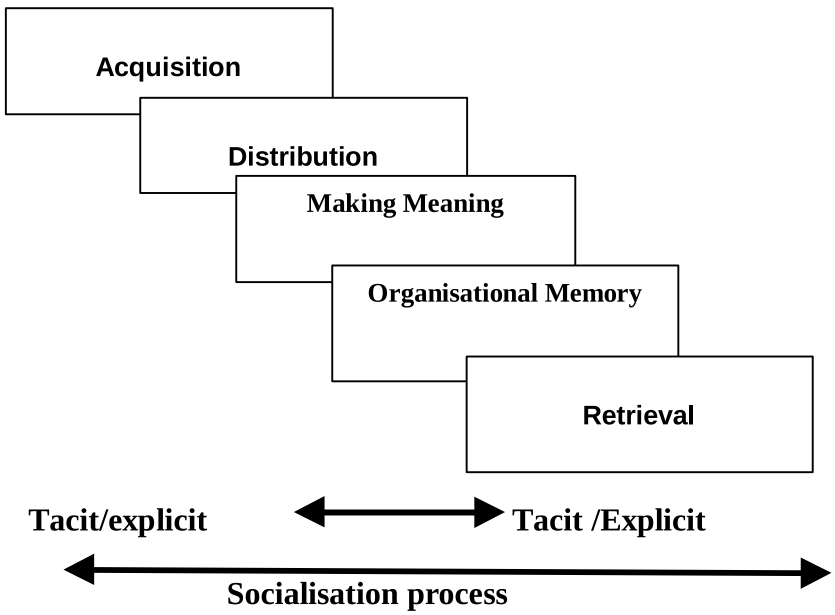
1 Introduction

Ability to transfer knowledge is among the key attributes towards building a learning organisation (Senge (1990), Love et al (2000) and Goh (2000). Studies made in construction organisations have indicated a number of barriers to learning (Boyd and Robson (1996), Bang and Claussen (2000), Love et al (2000), Anheim and Widen (2001) and Anheim (2002). Lack of time due to commercial pressures, practice of short-term problem solving due to pressure within the organisation environment and construction programmes and problem-solving approaches focusing on results and not consequences had featured as key obstacles to learning.

Professional consultants in construction are exposed to multiple projects of varying nature, different clients and suppliers. Such an environment offers substantial opportunities for learning to professional consulting firms through the diverse interactions that may facilitate cross- cutting of ideas and experience. It is of interest then to investigate to what extent are consultant- firms in construction learning organisations and to what extent these firms tap the learning opportunities offered by their working environment.

This article is based on data from a 19/25-questionnaire response and 10 oral interviews conducted to individuals holding executive positions in professional consulting firms in the Tanzania construction industry. The study had explored how professional consultant firms: acquire; distribute; make meaning; store and retrieve information. Data collected was analysed using a five-stage model of a knowledge transfer process (Dixon, 1992). Refer Fig.1.

Fig.1. The knowledge transfer process



2 Organisational Learning and the Learning Cycle concept

Learning occurs when an organisation achieves what it intended or when a mismatch between intentions and outcomes is identified and corrected (Argyris, 1999). Learning is not achieved when an organisation repeats mistakes, fails to adapt to customer needs and is unable to improve to meet rising competitive standards (Dixon, 1999). Dixon's (1999) model conceptualised learning as occurring in a cycle constituting of: widespread generation of information; integration of new/local information into the organisation; collective interpretation of information and having authority to take action. To operationalise Dixon's (1999) model an analogy in this study was made of the learning cycle to a knowledge transfer process model based on her earlier work (Dixon, 1992), Refer Table 1. Such an analogy has been taken based on: the existing close correlation in the measurable attributes of the two models (Dixon, 1992; 1999) and the close relation made of the learning organisation to the knowledge transfer concept in various writings (Vito (1999), Garvin (1999), Argote and Ingram (2000), and Goh (2000).

Table 1- The Organisational learning cycle (Dixon, 1999) and the knowledge transfer process (Dixon, 1992)

The Learning cycle (Dixon, 1999)	**Features (Dixon, 1999)**	**Knowledge Transfer Process (Dixon, 1992**	**Features (Dixon, 1992)**
Widespread generation of information	i) External sourcing of information through - customers, suppliers, new technology, economic conditions; ii) Internal development of new ideas including both processes and products - conducting organisation's business; analyses of mistakes, successes, experimenting etc,	*1 Knowledge acquisition*	i) External sourcing of information through - conferences, consultants, printed material, reports, customers, competitors, collaborative arrangements & new members ii) Internal sourcing of information - founders, existing technology, R&D, successes and mistakes, dialogue, critical reflections, etc
Integration of new/local information into the organisation	i) Dissemination of timely and complete information ii) Translating and /formatting information for use	*Distribution of information and interpretation*	i)Distribution - a)Intentional; written communication; internal seminars, workshops, , publications & formal training b)Unintentional; job rotation, task forces, informal networks
Collective *interpretation of information*	i) Organisation of dialogue skills; interact; critical reviews	*Making Meaning*	i) Interpretation - dialogue, critical reflection, process checks ii) Analysis of information- rationality, extrapolation from past etc.
Having authority to take action	Carrying out what needs to be done/ taking responsible action; have authority to apply discretion to make changes, control etc.	*2 Organisational memory* *Retrieval and re-use*	i) Internally - intentionally through records, reports, policies, core competence or -tacit means as through :culture & structure of organisation ii) Externally- through competitors, government records former members' etc II. Retrieval of information i) Controlled –critical reflection through individuals, or groups ii) Automatic- culture, structure, ecology, individual know-how

3 Findings from data collection

3.1 Knowledge acquisition

The study investigated to what extent is knowledge acquisition in professional consulting firms external or internal. Externally acquired, as through conferences, interaction with other consultants, customers, competitors, new members, documentation, joint ventures, mergers or consortiums. Internally acquired, as through the organisation's prevailing technology, know-how, experiences continuous process improvement, critical reflection, or questioning assumptions.

Responses revealed professional consulting firms in construction use both external and internal means of knowledge acquisition. At least 47 % of the firms had on average attended one conference per year. At least 78% of the firms have inter– firm linkages that facilitate sharing of information mostly through regular project meetings. External sourcing of information through documentation is high. At least 16 out of the 19 firms subscribe to journals both local and international. Incidentally the same numbers of firms reported links with competitors and perceive clients and customers as a source of knowledge acquisition. The same however, cannot be stated on collaboration as a means of acquiring knowledge. Only two firms had mergers and 12 firms had done jobs through joint ventures.

Strategic recruitment of new members to enhance knowledge acquisition in the organisations is not common (15.8% only) and when practised done on a part- time basis. The majorities perceive experience as the key source for internal knowledge acquisition. Acquiring knowledge through experimenting as in R & D activity is non-existent. Firms have innovated strategies to improve performance such as: the introduction of work on a contractual basis; flexible working hours; development of own cost data bank; enhancement of the working environment and the introduction of IT.

A significant proportion of firms (68.4%) take time for critical reflection; two executives in separate firms through interview admitted that although critical reflection occurred, it was not documented or shared with others in the organisation. A third of the respondents use the firm's financial cashflow as the indicator for performance. Only two firms used a deviation of the actual from the planned work; and only one firm had the clients they maintain as an indicator. With the current downsizing of firms and the subsequent skeletal structure due to less work in the building construction sector in Tanzania, firms reported to have less and less formal meetings for reviewing performance and have thus opted for ad hoc interaction. One Director of a firm stated

"*… With only two directors (architects) and one draughtsman –interaction is now spontaneous. We do not have formal meetings anymore*"

3.2 Distribution and sharing of information

Information acquired for it to be of use has to be distributed within the organisation (Sverlinger, (2000). Firms indicated a higher propensity towards distribution of information through intentional means. Written communication was noted to be dominant in distributing information complemented by face-to-face communication. Approximately 50% of the firms have a training programme in place. However, the training programme is done to assist registration of the junior staff and those who have not registered with professional bodies. Neither training programmes nor continuous development programmes exist for the already registered employees.

Internal publications as a means of distributing information are limited to the publication of the organisation’s brochure and only five of the nineteen firms have brochures (26.3%). “On the job training” is focused on employees who have recently joined the organisation. Firms practice what they refer to as “ a full cycle exposure” that is, exposing an employee to the full cycle of a process. A junior architect under supervision would be given responsibilities from preparation of the design brief to the production of working drawings. Only one firm had the practice of exposing the middle cadre employees to executive roles; an executive will have a middle management subordinate when meeting financiers or clients currently held by the organisation or potential ones. Only two of the 19 firms (10.5%) practice job rotation or use task forces for specific tasks. The current skeletal structure of consulting firms is perceived as attributing to existence of informal networks. It is perceived that, the structure of the organisation especially in terms of size and even the physical office set up facilitates a lot of interaction in an informal manner.

3.3 Making Meaning

Organizations can make meaning through interpretation or analysing information (Dixon (1992) and Sverlinger (2000). Interpretation of information is facilitated in dialogue, critical reflection, and process checks, taking action or unlearning. Making meaning through analyses is possible by rational analyses, extrapolation from past events, strategy formulation and use of decision support tools.

Respondents perceive dialogue and critical reflection, as the dominant modes of making meaning. A significant proportion (63.2%) cited facilitation of dialogue by firms as average while a lesser proportion (31.5%) perceived the effort as high. Critical reflections and process checks reported to be common between consultants, clients and suppliers during the design phase where cost plans are matched against cost targets. Extrapolation from past events is high (75%) and seen more as a natural phenomenon than a conscious effort in interpreting information.

3.4 Organisational memory and information retrieval

A majority (78.9%) of the respondents indicated key repositories of their organisations as records and reports. Stating the former to be in specific project files. Individuals as repositories where ranked next (63%) followed by the firms’ organisation structures (52.6%). External organisational memory is seen to lie mostly in clients, followed by other consultants whom the organisations had worked with.

Controlled and purposeful retrieval of information is the dominant mode in the consultant groups studied; for instance, certain details from drawings used in a previous project would be sought for use in a proposed project. The retrieval of information for re-use marks the creation of a new learning cycle implicating learning has occurred (Nonaka and Takeuchi, 1995).

4 Discussions

4.1 Information and knowledge acquisition

i) Experiencing and learning

The bias of firms taking experiencing as a key source of internal knowledge acquisition presumes experiencing necessarily implicating learning. A presumption that is not always true (Dixon, 2000). For learning to occur a reflection has to be made.

ii) Modality of inter- firm linkages-

Although firms reported inter- linkages, these links are largely formally created such as when firms work together through project teams. The sustainability of such links is doubtful, as they are not based on initiative. Professional associations could offer a media for informal inter-linkages. Although all firms studied are members of such associations, the opportunity has not yet been exploited.

iii) Collaborative arrangements-

Few firms have done jobs through joint ventures or had mergers. Surprisingly, such activities are not in formal records hence formally there are no track records of either mergers or jobs done in joint ventures by the registered consulting firms in the country. This is an indication that informal links exist within the industry as firms team up for jobs. Such instances are healthy environments for knowledge transfer and the creation of knowledge as they provide opportunities for sharing experiences and skills through a socialisation process (Nonaka and Takeuchi, 1995).

iv) Critical reflections on performance-

The financial statement being used as a tool for critical reflection by most of the consulting firms requires complementing with a knowledge focus. Firms need to critically review " what they have learned". Experiencing alone is not enough for learning to take place (Dixon, 2000). Firms reviewing performance need to reflect on what they have achieved, how and what they can adopt and carry over from their achievement. A measure of the clients they have been able to maintain over time as reported by one firm is a good indicator - but then, the firm needs to reflect what facilitated the achievement. Firms need to know how they have been able to maintain their clientele portfolio and what went wrong with the clients they lost.

4.2 Information Distribution

i) The full cycle exposure-

The "full cycle exposure" in lieu of "job rotation" practised by most consultant firms to junior members of staff has its limitations on the aspect of exposing the organisation to learning. Two aspects feature; first, such a practice does not acknowledge the dynamic nature of learning and learning is taken to be a synonym of training or lack of knowledge. The latter had also been established as among the barriers to organisational learning in the chartered surveying profession (Matzdorf et al., 2000). That learning is perceived "to equal training, lack of knowledge or qualification". Second, the absence of strategic job rotation limits individuals from being exposed to information beyond their immediate operations thus depriving organisational members understanding its business from multiple perspectives and thus fail to diversify their skills and information sources (Nonaka and Takeuchi, 1995).

ii) Informal networks-

The existence of informal networks in the organisations is a positive aspect for facilitating socialisation. Such socialisation may enable knowledge bound within individuals to be shared by others and also enhance collective interpretation, which is a crucial factor for enhancing organisational learning (Dixon, 1999) *iii) Tools support for interpretation*

Although tools support is not a necessary resource for information interpretation, it however enhances rational analysis and consistency in making interpretations. The lack of tools support in the interpretation of information in the respondent firms implicates a danger of biases or incorrect interpretations of information. Relying on human beings in information interpretation can attribute to flawed interpretation, as human beings are subject to a wide range of interpretative errors Garvin (2000).

4.3 Organisational Memory

i) Records and reports as repositories

Records and reports as key repositories in lieu of the organisation structure have limitation on enhancing organisational learning. Memory not being encoded in the structure of the organisation implicates a tendency to single- loop learning by the firms and organisations thriving to maintain the central features of organisational theory in use (Argyris and Schon, 1978).

ii) Individuals as repositories

Individuals as repositories for the organisation have both positive and negative repercussions. Value is added to the information stored by an individual, as on storing, a synchronisation to an individual's existing knowledge occurs. There are however possibilities of the stored information remaining dormant or lost if opportunities of retrieving the information do not occur, or the organisation loosing crucial knowledge when individuals leave the organisation (Prusak and Davenport, 1998).

4.4 Retrieval of information

i) Automatic retrieval of information

The fact that firms use less of the automatically retrieved information implicates that existing tacit knowledge in the firms is not fully utilised and that firms are governed by more structured and explicit information. The later may be good for creating order, but limits the autonomy of individuals or departments, an enabling factor for knowledge creation. Allowing members to act autonomously as in automatic retrieval of tacit information and make decisions will increase the chances of introducing "unexpected opportunities", a factor that could bring in creativity (Nonaka and Takeuchi, 1995) or act as an incentive to encourage new approaches and subsequently facilitate learning (Garvin, 2000).

5 Conclusions

The knowledge transfer process as practised by professional consultant firms in the Tanzania construction industry has shortcomings that bar organisational learning. Such shortcomings cross-cut along the whole process of the knowledge transfer. Featuring in the: modality of inter-firm linkages; tool used for reviewing performance; taking of learning as equal training or lack of knowledge; tendency to single-loop learning; limited use of tools support in interpretation of information; use of individuals as key repositories and the mode of information retrieval.

Firms need to capitalise on the existing aspects identified by the study as enhancing learning. These include informal networks, collaborative arrangements, the dialogue of project actors and the use of individuals as repositories of information. They should thrive to develop an infrastructure for organisational learning that will facilitate organisations through the learning cycle whereby there would be widespread generation of information form both external and internal sources; integration of new/ local information into the organisation; collective interpretation of information and authority to take action.

It is imperative for consultant firms in construction to realise that behaviours that define learning and the behaviours that define being productive are one and the same and that learning is the heart of productive activity (Dixon, 1999). There is thus a need for them to incorporate learning as an integral aspect of the day to day business of the organisation.

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On-Line Safety Management Processes

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Abstract

Recent developments in computer usage and easy access to Internet services have created a technology for safety managers to use in safety program development. This paper describes a methodology for using Internet services to provide a safety management system that helps prevent accidents, decrease injuries, and lower workers' compensation claims. The system is based on a four-phase safety management process system that is built into the design of the Internet system. This four-phase process includes: Phase I Auditing and Assessing; Phase II Program Development; Phase III Implementation; and Phase IV Measuring and Monitoring. Phase I supplies auditing and cross-referencing applications such as interactive tools, discussion boards, and personal assistance to audit worksites and analyze job hazards and hazardous materials. Phase II contains interactive applications to accomplish safety planning, policy making, and establish written safety programs and emergency response programs. Phase III offers access to new ideas, creative materials, and applications to allow the user to establish job hazard controls, communicate hazards, and develop training and safety skills. Phase IV establishes interactive tools, a learning center, and reference areas to assist with logging injuries and illness, investigate accidents, document worker training, and monitor government changes. A survey will be conducted of users of and potential users of Internet services by evaluating the systems safety management content, regulatory content, and the application of safety and security measures to a jobsite. The paper will conclude whether or not this four-phase system will result in accident prevention, decreased injuries, and reduced workers' compensation costs.

Keywords

Safety Management Process, computer based online system

1 Introduction

Injuries in the workplace cost American companies an average of $40 billion per year. This figure is comparable to the total annual sales revenue for a top tier *Fortune 500* company. While that alone is staggering to consider, the real drama is realizing that the rate at which this number is increasing is about 3% annually (1 BLS). That means that the cost of workplace injuries is rising faster than the nation's inflation rate.

Upward cost trends like this hardly go unnoticed. In fact, over the last three years companies have dramatically increased their awareness to workplace safety issues. Safety professionals are quickly joining the ranks of other executives whose results are measured and reported on an annual basis (2 Liberty Mutual). That means safety efforts will at some point, undergo the same scrutiny that other departments face when their results negatively impact the bottom line.

A safety program may be defined as the procedures, rules, training, communications, emphasis, and the development of a work culture, which has been directed at the reduction of risks, control of hazards, and the improvement of efficiencies of an organization. It is a written plan that provides for the safety of employees and the business. The key to the program is that there is evidence that the program is site specific that is it is implemented at jobsites where workers are exposed to risk. A construction company must have a written safety program in order to effectively manage safety and to prove that they actually implement safety at their construction sites. A written safety program with its accompanying records and reporting procedures can be the documentation of the safety efforts of a company. The reporting difference may pose some challenges to safety practitioners, especially if the safety results must be reported in terms of their financial impact. However, the bigger challenge will be making sure that all safety efforts are properly focused to reflect the affects on accidents, injuries, and workers' compensation totals. A suggested method to manage safety in a construction company is to utilize an on-line safety management process. This paper will discuss such a process.

2 The Safety Management Process

Safety management is an integral part of the overall management processes of a construction company. The primary goal of the safety management process is accident abatement. Accident abatement maybe further defined as the proactive prevention of accidents before they happen.

Managing safety processes is essential to accident abatement. Managing safety is relevant because accident abatement is one of the primary reasons that construction companies hire and employ safety professionals.

It is often stated by employees and front line supervisors that accidents happen. Many workers and managers seem to believe that accidents will happen due to unavoidable risks involved in their work activities. They tend to believe that they have little or no control over their work activities in relation to accident prevention. However, accidents do not have to happen. Accidents are preventable. An established method to prevent accidents is called the safety management process. It has been shown that when safety management is practiced in a structured process safety managers become more effective. Moreover, when that process is interactive and highly integrated so that it follows a logical sequence of events the process helps greatly to reach desired safety outcomes.

The safety management process is cyclical and continuous and includes four phases. These phases are:

- Phase I – Auditing and Assessing

- Phase II – Program Development
- Phase III – Implementation
- Phase IV – Measuring and Monitoring.

. This process is continuous with each phase including a specific set of activities that are dependent on the next. When managed well, this process helps to prevent accidents, injuries, and lower workers' compensation costs.

2.1 Phase I

The goal of Phase I, the Auditing and Assessment phase, is to identify hazards and calculate risk. To do this, safety practitioners must perform physical inspections of their jobsites. The on-line site provides auditing and cross-referencing applications to help with this effort. For example, the on-line site's tools enable jobsite audits, hazard analyses, hazardous material audits, security analyses, and comprehensive assessments of current working conditions.

2.2 Phase II

Once both the existing and potential hazards have been identified, safety practitioners can chart their courses of action and determine how to manage the risks. This leads to the goal of Phase II, the Program Development phase. The on-line site provides interactive applications to help with this effort. For example, the on-line site enables goal and objective setting, safety planning, and policy and procedure development. Planning ahead is essential to accident prevention

2.3 Phase III

When the goals and objectives have been set and the plans have been established, the logical next step is to implement them. Implementation is Phase III of the safety management process. The goal of this phase is to increase the safety awareness of workers and motivate them to be involved. The on-line site helps foster an overall desire in workers to care about working safely with presentations, training, and incentives for skill development and tests for accountability

2.4 Phase IV

In Phase IV, the Measuring and Monitoring phase the goal is to review progress and make revisions so that all safety efforts yield results, continuously. The on-line site enables safety practitioners to investigate accidents, log injuries, spot trends, and report the results. The on-line site also enables brainstorming and new idea generation so that new objectives are set practitioners can start working towards meeting; leading back to Phase I.

2.5 Creating and Evaluating the Safety Management Process

Every safety management effort should begin with identifying hazards. In a sense, this is the most crucial phase of the entire process. The tendency of many safety practitioners however, is to react first and move straight into implementation. Doing this compounds the risk element because missing minor details can lead to disaster.

The question then is for a construction company is how to create a cost effective safety program within the culture of their company. Creating a written safety program and managing the safety processes of a construction company could be a time consuming effort. When a mangers time is limited due to the duties required to manage construction projects, an efficient method is needed to manage safety. Otherwise not enough time will be given to the safety management process. One possible method is to create a safety program from a computer based, on-line reference system that is updated to meet current safety regulations. Utilizing this method to create and prepare a written safety program could be an effective safety management tool referred to as an on-line safety management process.

3 Evaluation of the On-Line Safety Management Process Website

Table 1 is the summary of the responses to the questions asked in the survey of 102 respondents who were not familiar with the on-line site, but were computer literate.

Table 1 – Summary of the Responses of the On-Line Site Survey

Survey Question	Yes	No
1. Is the site organization easy to understand?	74	1
2. Is the necessary safety information available?	83	0
3. Are the safety management contents adequate?	60	0
4. Are the applicable safety (OSHA) standards covered and accessible?	77	1
5. Can the site information be easily applied to a construction jobsite?	82	1

4 Evaluation of the On-Line Site by Respondents Not Familiar with it

4.1 Is the Site Organization easy to understand?

The website is well organized and easy to understand and takes only a little time to learn how to navigate the website. The most effective tools on the site are the interactive programs for safety and audit programs. Users can view information already in the site database or they could create their own safety plan, training program, or checklist for safety audits.

If a company encounters a safety problem, they are able to research the problem at the site and with that knowledge solve the problem. Another feature of the website that makes it easy to use for safety managers is by linking each safety program topic so that the user can easily customize that safety program to meet their particular job site needs.

The on-line site has done an extremely impressive job of organizing and putting together such a large quantity of safety management information. The site is designed to help safety professionals manage their safety processes by enabling them to make informed decisions faster, take action, and stay focused on getting the results their company expects. It is an easy to understand electronic system, which provides safety, and compliance information that is of enormous assistance to all who desire safe work sites.

4.2 Is the necessary Safety Management Information Available?

The on-line lays out the necessary information that the management of a construction company would need to implement a proper working safety program. The only thing that the on-line site does not provide is a safety supervisor; however, with the personal assistant section management has access to 20 editors and consultants in the safety industry. Another useful part of the website is the "Interactive tools section." This section helps a construction company create and write specific safety plans ranging from Accident Reporting to Workplace violence. The on-line site helps create policies and plans that adhere to OSHA, Environmental, and insurance requirements. They do this by providing a template for the policies and implementation of the specific plan.

The on-line website has an abundance of material on construction safety from the OSHA standards, prewritten checklists, informational videos, company policies, safety procedures, and the particular laws that each state has issued concerning construction safety. Training materials are comprehensive and easy to access. They include topic introductions, outlines, quizzes, handouts, and presentations. These materials provide safety instructors with the necessary tools to effectively train company personnel and allow the instructor to focus on thee task of providing a safe workplace through knowledgeable employees. The website has an overview feature that provides a key example of how to establish an overall safety program for a company.

4.3 Are the Safety Management Contents Adequate?

The site can help safety managers promote safety in many ways. Most of all, it gives safety managers a way to easily access quality information quickly.

The construction safety management content of the website is helpful in establishing a safety program or updating an existing program. There are a variety of learning tools available for assistance. For instance, there are safety plans available for all construction needs. You can take a general existing plan and shape it to the needs of your company. This is done by taking an existing template that is provided on the website and adjusting it to fit a company's needs. Along with safety plans, there are various other documents to help in the management of construction safety. Some of these documents include:

- Policies and procedures
- Safety training program
- OSHA safety checklists
- OSHA accident reporting forms
- Safety Audits

The website is excellent for safety management. To be able to manage safety on the jobsite you must have a written safety plan that is in compliance with OSHA but is tailored to a company. There are written safety plans, which range from many aspects covering the OSHA standard. These plans are for an actual jobsite and comply with the OSHA 1926 Construction Safety Standards. The safety management content contained in the on-line website is helpful to anyone who needs examples of safety ideas or who wishes to create their own written safety plan. For example, a contractor wishing to develop a safety and health program can find what information OSHA requires, such as hazard prevention and control, information and training, and contractor responsibilities. An employer would be able to fulfill his basic obligation to systematically comply with the hazard prevention and control requirements of the OSHA standards with their safety program.

The on-line site provides a variety of information covering safety management. A topic index is accessible from the home page that contains an alphabetical index covering any topic related to construction safety. Clicking on a topic leads to the main topic page. Clicking on the Explanation leads to detailed information on the topic broken down into major areas such as background, work classification, scope and application, record keeping, hazard communication, and more. This setup makes it extremely easy and fast to find information on any safety topic of interest. Managers no longer have to sit and read the OSHA standards and then try to interpret the information that the standards contain. The website has done this for them.

4.4 Are the Applicable Safety (OSHA) Standards Covered and Accessible?

The on-line site has researched all current safety regulatory information for construction that is available. Four major areas are covered in this area. which are workplace safety, transportation, environmental, and employee elated information. With such a wide array of information that the on-line site has cataloged on its website, anyone using it can be assured that they are following the appropriate standards. The on-line site has every state's specific regulatory content included within it. With all the regulatory content that the site provides, and the different methods to access that content, there is no excuse to be ignorant of any federal or state regulations.

The regulatory content of the on-line site is remarkable. Not only is all regulatory information included within this website, the information is up to date, ensuring that companies do not fall behind in their safety practices. Within the index of topics the site provides applicable regulatory information. This information follows the OSHA standards as well as any federal or state regulations that are in place for the specific topic. The learning center link on the home page takes the user to interesting topics and recent updates to regulations. Video and text versions are included to provide the material in understandable and innovative ways that can be quickly shared with other co-workers. The reference section on the home page allows the user to find the most current regulations using the regulation number, the industry of interest, with even Department of Labor and NIOSH regulations included. There is a state directory with regulation information on a variety of topics and a discussion area dealing with regulation information where users can obtain answers to frequently asked questions, use a personal assistant, or participate in industry discussions. These tools make it easy to keep up with the constantly changing regulations and they help accomplish this necessity in a more efficient manner. A website member (subscriber) will always be informed of regulation changes as they happen. Compare this to the efficiency of obtaining the same regulatory information on a monthly or quarterly basis by the use of a journal or newsletter.

4.5 Can the On-Line Website Information be Easily Applied to a Construction Jobsite?

Under the 'interactive tools' section of the website various written programs can be edited directly or downloaded to a computer and edited to fit the specific job site. While these programs are a good start, they do not contain specifics for a particular job site. These written programs can be edited to include the names of the people within the organization that are responsible for safety and also specific procedures or policies that the company may have or needs. Edited can be accomplished in one of two different ways. The first way to modify the written safety program is by answering a list of questions provided by the website. Once you answer these questions the responses will be entered into the safety plan in the appropriate place. The plan is stored so it can be printed or referenced at a later date. The second way to modify the program is to download it directly to a computer and edit it using a word processing program. These methods make the website useful by making the safety plan job site specific.

In order to apply the safety measures at a jobsite one would first outline all of the construction activities that would be going on throughout the course of the project. Next look up any and all standards that apply to these activities. After noting all the project's safety requirements an extensive daily jobsite inspection checklists could be prepared by members of management for use by site front line supervisors to ensure compliance with the standards and the prevention of accidents. All these steps are easily accomplished with the assistance of the website.

4.6 Negative Comments

Only two negative comments were received out of the hundreds contained in the survey. The first said that reliance on the site would make the user not utilize any other source of safety information and thus miss obtaining valuable input from other safety sources. The second comment thought the site concentrated on helping companies avoid OSHA citations rather than preventing accidents. The respondent felt that the website was more concerned with protecting companies from monetary loss and penalties than with protecting people from injury. This is could be a significant problem in the construction industry. Often, in construction, it seems that safety is largely ignored just because it is inconvenient and the only reason safety is observed is through the fear that OSHA will come and cite a company if they don't comply. This attitude is largely counter-productive and it almost seems as if the site is supporting this mindset. Starting the articles with a description of the accident could change this quite easily by heavily emphasizing how the workers were injured and what could be done to prevent reoccurrence of the accident.

5 Evaluation of the On-Line Site by Users of the Site

The on-line site conducts surveys every quarter of approximately 150 of the on-line subscribers. The findings and results of these surveys indicate that there is an emerging trend by the subscribers. Over 90 percent of the subscribers consistently state that they would probably or would definitely recommend use of the on-line site to others. Satisfaction among these subscribers is also high with over 90% consistently expressing satisfaction.

6 Conclusions

The use of the website by construction companies in creating and implementing safety programs is a successful tool.

People not familiar with the on-line site found the site to be easy to use and worthwhile. In addition the site has the safety management available to implement a working safety program. The site the applicable regulatory information accessible for utilization by site subscribers. Finally the on-line site information can be easily applied to a construction site.

Persons subscribing and already using the on-line site expressed a willingness to recommend use of the on-line site as a tool to use to other safety practitioners and consistently expressed a high rate of satisfaction.

More research needs to be done as to the successful application of the website to construction site safety programs.

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Quality assurance in construction projects: how many?

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Abstract

The main objective of the paper is to introduce a method to improve the quality during the conceptual stage of construction projects.

Quality in the conceptual stage usually includes different views: from one hand the formal processes of project preparation and in the other hand the project idea and quality performance of the building as a result of this conceptual process. Both views complete the global idea of quality in projects and are very related to the communication among client, designer and constructor. Therefore, quality assurance must include these aspects in order to achieve a good level of quality in project engineering.

In this paper we will include information of a developed practical method to assure a high level of information among the different actors at this stage but without missing the compulsory documents to be realized (quality assurance procedures) to allow quality evaluation. Usually authors consider the conceptual and design stage the most important to obtain a well defined project.

As a result of the method application, we have designed a computer tool to develop a series of protocols where clients can introduce his necessities and specifications. Once they are stored in a database, designers can process and translate them into constructive requirements. This tool will also establish the guidelines to assure a correct redaction of a project so as to assure its viability and consequently to obtain the actual obligatory assurance. It will be like a platform where clients, designers and quality control figures have access to the project information to give specifications, process these specifications and control the quality of the project.

Keywords

Construction quality; conceptual quality; methodology

1 Introduction

The construction is one of the sectors where quality doesn't have the importance that is deserved. This is owe because construction projects are always "unique" and different from another done before, making difficult to establish universal parameters of application in all construction projects. In every project different interested parts take part (mainly the client, the designer and the constructor), that have different objectives because of a different vision of quality in construction.

On the one hand, the client looks for the maximum quality in the functionality of the project without unnecessary costs and without delaying implementation times. On the other hand, designer looks for a quality level that supports the satisfactory performance of the system and serves him to improve his personal reputation (taking care of the aesthetic of the final solution), but like the client, trying not to incur in unnecessary costs and over costs.

Actually, there are a lot of rules and guidelines reference to the quality of products and services, for example products like cars, computer, etc, or services like consulting, assuring, etc. In against, there are a few or few rules or guidelines referring to the quality of construction projects, from the conceptual stage to the construction and maintenance stage.

In this paper, construction projects has been divided in two groups or stages: designing (conceptual) and execution. In the first one, it includes from when the client has the idea to develop the project until the development of the documents. It is evident that it has to include client's ideas and requirements, and contain all the sufficient and necessary information to construct the building. In this point, the communication between client and designer has to be perfect. This stage is the most neglected from actual rules and guidelines.

Project execution is the second one. It includes the transformation of the specifications of the documents in something physic (normally buildings).

Therefore, the integration of the quality in all the stages of a construction project is necessary. Nowadays, in the execution stage, there are quality systems in construction companies. Some studies affirm that some of the quality problems have its origin in the deficiency of specific definitions or omissions of details in conceptual parts of a project. For all of this, we have concentrated in the first part of a construction project: the quality in the conceptual stage.

2 Aims

The main objective of this paper is to show the improvement of the quality in the conceptual stage of construction projects. The way to achieve this is doing continual quality evaluations in different moments of the conceptual stage. By doing this, possible errors will be detected and corrected before the end of the project. The idea of doing quality controls at the end of the project is old. In this case, the idea is the securing of the quality during the conceptual stage. The objective is to create some general guidelines to allow developing evaluations of the idea and compare it with the expected results, so that the aims and requirements of the client are fulfilled.

3 Background

Going back, a project is defined as the combination of different kind of resources (including human resources) put together in a temporal organization to get a determinate purpose. Obviously, the most suitable direction of all the resources to obtain this purpose is a process of resources optimisation management. The main purpose is centred in obtaining (in a construction project) the global objective in the system of possible objectives: of quality (from the functional point of view or details), of costs, of execution periods, etc.

Design process and building construction is subjected to some complications, restrictions and conflicts, often due to the mutual incompatibility of objectives between the different involved actors.

Other problems are based on the use of the building during its useful file but sometimes these problems are difficult to envisage during the design stage.

Generally, there are a set of possible factors that can influence the quality of the buildings. This can be divided in four categories:

- Quality of design studies.
- Quality of formal processes of project preparation.
- Quality of the construction process.
- Quality of the used products and systems.

Therefore, construction quality is not only from the physical aspects (structure, foundations, facades, etc.) but also all the aspects referred to client's satisfaction when acquiring the product. Therefore, the aspects as distribution, functionality, aesthetic, etc., which are necessary and important for the client, de designer doesn't pick them up and consequently they are not reflected in the building.

From the 4 categories of the factors that influence the quality of the buildings, the two first ones should be taken into consideration in the design stage of the project, while the others in the execution phase.

Quality is not only assured in the execution stage of the construction project but also in the conceptual or design stage. Therefore, to know the requirements of the client is very important.

Another general aspect, that makes the quality assurance more difficult in construction projects, is the multitude of different involved agents. Consequently, we can find the client, the promoter (that can be the same as the first one), the designer, the contractor, subcontractors, etc. It's necessary to clarify from the very beginning the responsibilities, concerning quality, of all the participants. If not, the quality of the final project and building could feel the effects of it. This responsibilities should distribute in accordance to the abilities of each agent.

For all of them quality has to distribute and leave very clear from the beginning of the project which are their responsibilities. In the opposite case, the quality at the end of the project could be suffered. This responsibilities has to be distributed in agreement with the ability or speciality of the agent. So, if the client delegates all the responsibilities of the project to someone else, they will need to have the necessary aptitudes to do it and if they are a constructor company, they will need to have knowledge and experience in this area. However, if the client is looking for a more direct relationship with the project, the requirements will be more technical.

This situation is particular to the construction industry, because contractor and designer are normally separated organisms while in other industries they take part in the same team.

4 Quality in the conceptual stage of the project

As said before, the conceptual stage of the project includes the project design which will be carried out in the execution stage. In this first stage, there are three important parts:

- Quality in the proposed solution.
- Quality in the description of the solution.
- Quality in the justification of the solution.

The first point is related to the quality of the project idea, trying to adapt them to the requirements of the client. Both following points can be put together in only one that considers the quality of project documents (formal aspect) in order to assure that the documents allow to build the building that is projected. Consequently, we can distinguish the two basic qualities of the conceptual stage of the project: the quality of the idea and the documental quality. Obviously, both qualities have to be carried out in order to assure the quality in the design.

Some time ago, when considering the objectives of the project the attention was directed to the methodology and procedures to obtain the corresponding execution times and to adjust to the cost of the investment. The objective of the quality has been considered as a separated specification of the system of Integrated Direction of Projects, without paying the same attention than the destined to cost management and execution time. Currently, this vision has changed. Now, the quality is an objective to establish, control and direct, to be able to obtain it at the end of the project.

Some authors, who have studied the introduction of quality systems in the design process of constructions, insist on that a *good communication between the different agents* is the most important aspect to obtain a quality product and that satisfies the maximum expectation of all the implicated parts. Due to this, it appears the concept of triple paper of the different agents. In the following figure, we can see communication between the different parts is essential. The client requirements must be transformed, by means of designer, in documentation (drawings, specifications, etc.). At the same time, this documentation has to be converted in a building that satisfy all the necessities of the client, built by the constructor (closing the triangle). Therefore, the information transfer is essential to reach the objectives of project quality.

It's possible that different engineers (designers) participate in a project, as well as different constructors, implicating different quality systems. This fact involves that in the worst case we are in front of a cobweb of systems and different approaches of the quality.

Consequently, there are different qualities depending on the different stages of the project but each of them are part of the global quality of the final building.

The controversy raised in this paper is to be able to evaluate the quality in the conceptual stage of the project so as to avoid finding at the end of the project that specifications have not been fulfilled, and therefore, the initial objectives of quality have not been reached.

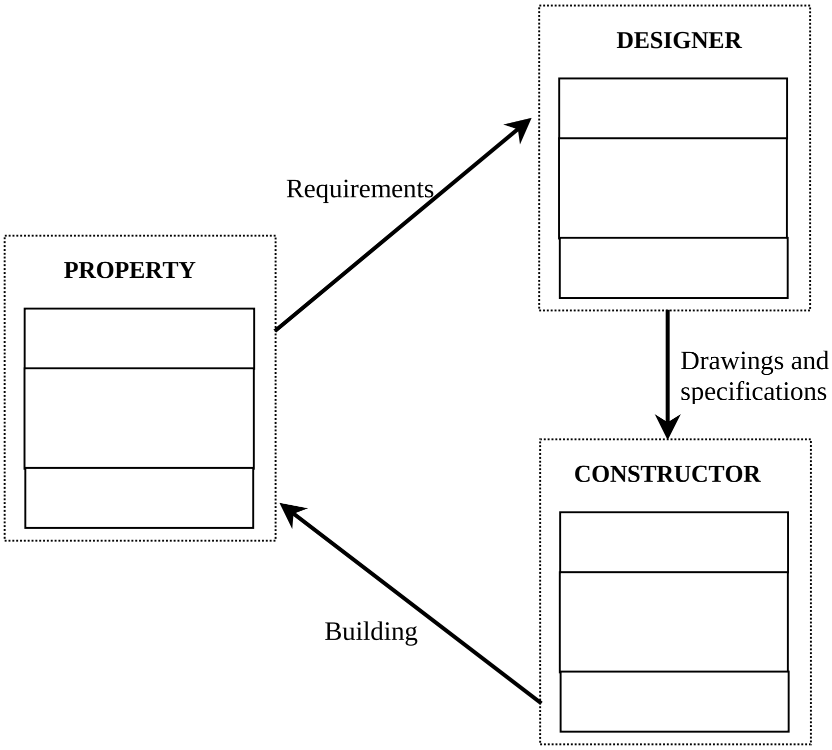

Figure 1 – Concept of triple "paper" of the different agents

5 The proposed method

The method that is proposed in this paper is based on the quality improvement in the conceptual stage of a project. In this method the steps to adopt by the client and by the designer are set so as to achieve the desired quality in every moment of this stage.

Until now, the quality control in the conceptual stage of the construction projects was basically focused on formal aspects, quality was only checked for the document format.

In this method, formal aspects should be controlled but also the quality of the idea. Actually, the aim of the method is to evaluate if the project documentation fulfils the requirements of the client in the whole process of the development of the documentation (not only at the end of the stage). That's why periodic evaluations along the conceptual stage of the project should be done.

Obviously, we should develop a working system to identify in what moment of the conceptual phase of the project to carry on with these evaluations. We should also define the best way to do so and the utility of these so as to determine if they are necessary for the quality improvement of the projects.

To develop an efficient method, information from the client and from the designer should be perfectly identified but also interconnected one to the other so as to be able to transfer information between them. This information exchange is basically useful for not only for the client but also for the designer to check if the desired specifications are being fulfilled. Moreover, it will be useful for a third persona who will be in charge of carrying out the quality control and evaluate if the specifications are being fulfilled.

To improve the quality in the conceptual stage of the project is necessary to do some evaluation during this stage but, how many? We plan to have one at the beginning of the conceptual stage (Ai) and another at the end (Af). Between them we should do as many evaluations as necessary (An). The first evaluation is done when the initial information from the client is given (before starting to write the documentation); the second one is done when al the documentation is finished and controls if the documents fulfil the specifications of the client and also the formal aspects of the documentation. All the other evaluations are done to check the exchanged information between the client and the designer.

In the Figure 2 we can see a schema of the proposed method.

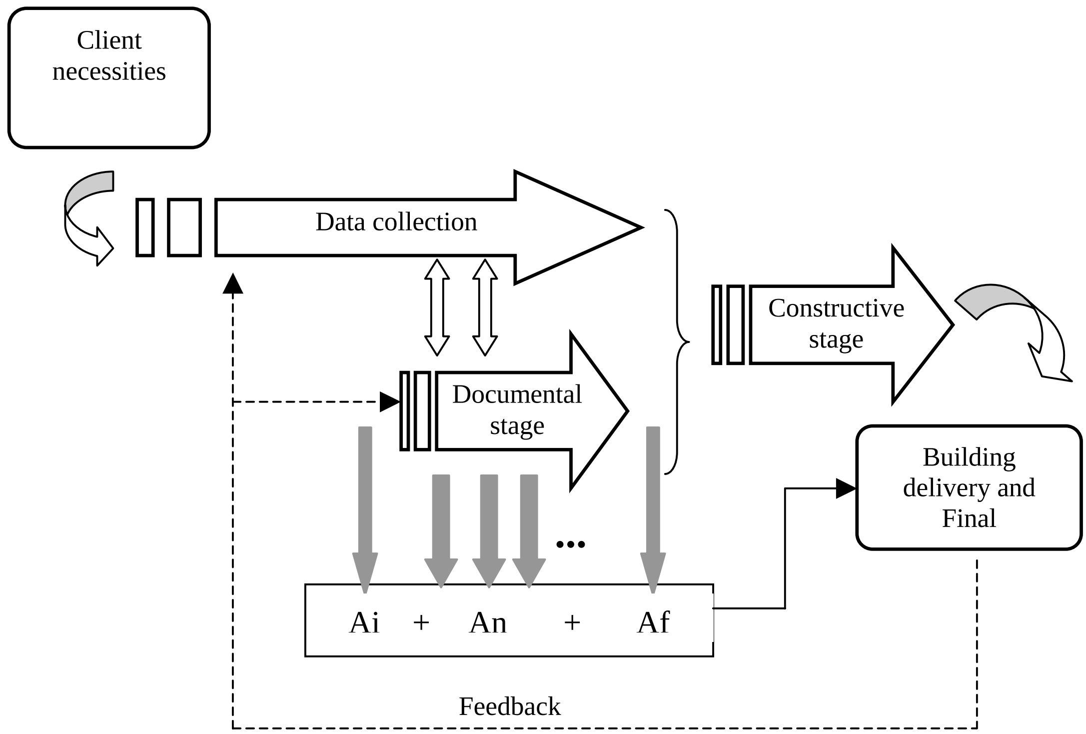

Figure 2 – Schema of the proposed method

Carrying out spontaneous quality intermediate evaluations implies that the client and the designer will be able to know the evolution of the project whenever they want.

It’s important to know that in Figure 2, the data collection and the documental stage are part of the conceptual construction project phase (design) while the construction stage concerns to what is usually called execution phase.

We should point out that each project is different and not all developed aspects will be useful for all the projects. Actually, the aim of this method is to develop a generic model or guideline to use in different kind of projects.

For the application of this method we have developed two aspects: the first one is a procedure to elaborate the evaluations and the second one is the tool to carry out this evaluations and get the desired results (to facilitate the task). To do so, we have elaborated some procedures to speed up the quality evaluation in the conceptual stage, fulfilling the requisites of the client and of the actual legislation and to unify the documentation of all the projects. Furthermore, we have developed a tool to allow accessibility, reliability, version reposition, ubiquity, etc of the information for all the implied parts.

5.1 The client's function

Firstly is very important which information to transfer from the client to the designer. It must be considered that sometimes the engineering knowledge of the client are poor so that a very high levelled questions might not be useful for the final objective. The information can be divided into four points (Casals and Roca, 2000):

- General information of the client (basically business activities, etc.)
- General information of the use of the building and the activities to carry out
- General information of the solar
- General information of the building

These four well developed specifications might be enough for the owner and also for the final user to clearly define its necessities.

5.2 The designer function

When the client has defined his purposes, the designer has all the necessary information to evaluate the economic and technical viability of the project. All the information from the client should be translated into technical specifications. That's why it's very important to create useful procedures for the designer no to forget any aspect in the project. In a similar way and by feedback, the designer can change the basic specifications if there is any legal or constructive incompatibility bringing new alternatives.

Consequently, the designer handle the information to generate different useful alternatives for the client so as to be able to change them if it's convenient. So, the designer should assure the quality in two aspects:

- Content evaluation of a project: it refers to some aspects evaluation like functionality, building aspects…, defined by the client and should be fulfilled.
- Format revision of the project: it refers to those formal aspects of a construction project like the title and its documentation: general index, memory, annexes, plans, specifications, measurements, estimate and when necessary studies with self entity (UNE 157001:2002).

Analysing all the information is obvious that the success of the method depends on the correct use of the information. To assure this correct use of the information we have developed a computer tool for the management of the information.

6 The tool

As said before, to carry out a correct quality evaluation of the conceptual stage of a project I s necessary to use procedures. When they are established, we should find resources to carry out them. This resources should facilitate the projects quality improvement task.

Firstly, all the participants (client, designer, constructor, quality control entities, etc.) should have a simple access to the information so as to join all the necessary information to help the other participants do their tasks. Besides, this information should be subjected to change for those required parts, so all the information should instantaneously actualised when somebody realizes a modification.

This tool should also include all kind of necessary information to elaborate a project (word documents, AutoCAD, excel, etc.). All the information will be stored in a unique database, which can be consulted by anybody and by anywhere. This will avoid documentation errors.

To do so, we have developed a computer tool. The main objective of this tool is the ubiquity, that means to share information making it accessible from anywhere to the related persons. The answer to that requirement is (of course) Internet and mobile access (in any way, WAP, GPRS, UMTS…) to it.

So, the tool will be focused on showing data through HTML viewers, transmit data on plain text file if necessary, managing data through HTML viewer or application interface.

Of course, these data will be kept on a Data warehouse where the whole information of the project and its environment will be kept.

In order to facilitate the implementation and make it available to everybody, we can use standard applications to feed data to Data warehouse.

We will choose Microsoft Office tools as well as Microsoft Project and Visual Basic to develop this tool. The reason is the widespread of these tools versus others (i.e. Sybase Power builder), that can be more powerful but SMEs might not have this software.

For Data warehouse engine we will also choose Microsoft Access. Even it’s not considered a real database engine (it’s not a transactional database engine) it’s easy to use, widespread all over the world, and if necessary, it can be exported to more powerful database engines (SQL server, INFORMIX, ASA, …).

The tool has a unique database where everyone (with previous authorisation) can get the information related to his role on the project. Joining all the data into one data warehouse will avoid data duplication, misuse of information and possible mistakes made by not using the latest information of the project.

The result of this tool will be a cooperative workspace on internet/extranet/intranet that will allow the user to see on real-time the state of the project.

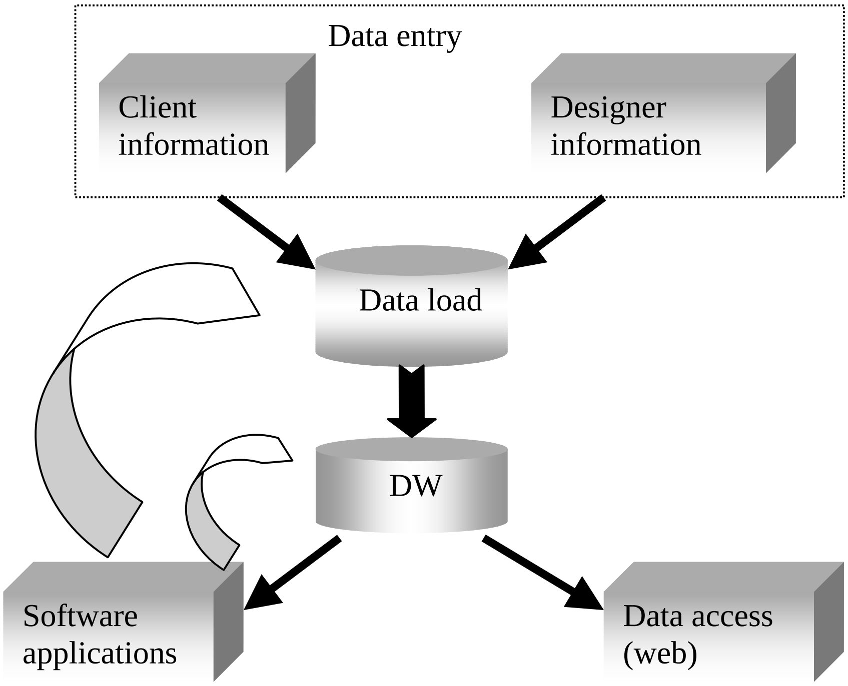

Figure 3 – General structure of the proposed tool

7 Conclusions

The construction sector is one of the most precarious due to its working conditions and also because of the scarce attention paid to quality assurance in the design stage.

Regarding this last aspect, we can take into consideration that the actual buildings are not suitable for the client necessities and this problem has its root in the conceptual stage of the project. We can see many communication problems between the client and the designer in the conceptual stage. Normally, the client knows what he wants but it's very difficult for him to express it and to make the technical specification. On the other hand, sometimes de designer only takes care of the appeal of the building so the qualitative / functional aspect is given up.

To improve the quality in this stage is necessary to improve the communication between client and designer so as the client can transmit in a easy way his necessities and the designer can follow them.

In this paper we have described a method and a web computer tool to help transfer all the information from the client to the designer. This computer tool not only improves the communication but also reduces costs, lets the client know the evolution of the project, improves the image of the business, etc.

Therefore, we totally believe that with this methodology the quality on the conceptual stage of the project can improve.

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Creating a Plan for Quality Control on the Construction Jobsite

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Abstract

Construction contractors manage their projects to ensure that jobs are completed on time and within budget. While items such as safety and quality may be deemed important, many foolish contractors take risks and sacrifice these two qualities in order to cut project costs and save time. However, it is a well-known fact that a proactive safety program can indeed be used to lower costs attributed to injuries and time wasted on accidents. In the same manner, a detailed QC program implemented on the jobsite will also aid the contractor in saving time and money. There are many benefits for managing quality on the jobsite. In addition to increasing customer satisfaction, higher quality eliminates the costly need for rework, and thus improves productivity of the workforce since work is performed correctly the first time. Quality Control (QC) Plans should be created and implemented to dictate the daily management of quality on the jobsite. This paper presents guidelines to assist in the creation or improvement of a jobsite QC-Plan based on the personal experiences of the authors.

Key Words

QC; customer satisfaction; rework; construction defects; inspection

1 Introduction

The most common cause of defects on the jobsite stems from the lack of QC during the construction phase of the project (Poles 1997a). The American Heritage College Dictionary defines the word *defect* as an imperfection that causes inadequacy or failure. Generally, defects in construction work are defined as any of the following situations (Poles 1997b):

- Violation of Building Codes
- Failure to build according to accepted trade standards for workmanship
- Non-compliance to requirements stated in the project plans and specifications

It is the responsibility of the contractor to provide the project owner with a facility that meets or exceeds the quality standards required by the contract documents. Quality is defined as the degree or grade of excellence, often meeting the requirements of a high standard (Costello 1993). A few common examples of qualities that do not conform to requirements are provided here from the Wonderful World of Structural Engineering web page (2002):

- Financial and speed considerations given more importance than quality
- Poor workmanship
- Poor materials
- Ignorance
- Greed (providing cheaper/lower quality products)
- Negligence

Effective QC will eliminate these low-quality conditions and lead to fewer mistakes by ensuring that work is being performed correctly. Since the need for corrective rework is eliminated, there will be a reduced waste of project resources. As a result, lower costs, higher productivity, and increased worker morale will lead to a better competitive position for the company (Deming 1982). Lost future revenue and the loss of customer goodwill due to low quality will also be minimized, although costs due to customer dissatisfaction are hard to track (Atkinson 1991). Creating a QC plan allows one to pre-plan the means required to obtain the desired quality of work on the jobsite. Although documents related to quality will vary among different companies, this paper provides the reasons and guidelines for creating a basic QC plan.

2 The Need for Quality Control

Low-quality work and the resulting customer dissatisfaction can lead to costly repair work and/or removal from consideration for future construction projects. An example of this is shown in the events that occurred during the construction of a $54-million army barracks project in Fort Bragg, North Carolina, as related by Korman (1997). It was discovered “that crews constructing the [concrete masonry block wall] buildings failed to place, properly space, grout, or use [reinforcing] bars of the right size in load-bearing walls.” Rebar laps at the connections between floors and walls were also missing. Due to the “gross incompetence or deliberate disregard for the terms of the contract,” construction was halted until destructive testing determined the extent of the reinforcing steel deficiency. As a result of the amount of “extensive remedial work” required, the project was scheduled to be completed “16 months beyond the original completion date” (Engineering News Record 1997). An exact dollar amount of the corrective work is not known, but it is believed that the total of these tests and repairs resulted in “millions of dollars” in “extra costs” to the contractors involved (Korman, November 17, 1977).

3 What is Quality Control?

QC is an aggregate of functions designed to ensure adequate quality in manufactured products. This is accomplished through an initial critical study of the intended design, and the study of the materials, processes, equipment, and workmanship required. These studies are followed by periodic inspections throughout the construction. Additionally, an analysis of inspection results is used to determine the causes for defects, and tracks the removal of these deficiencies (Costello 1993). In construction, QC includes activities taken by the managing contractor to ensure that materials supplied and work performed on the jobsite meet the quality standards established in the contract documentation, plans, and specifications. Controlling the quality of work performed is a crucial part of the construction process. Many times, construction managers view quality, cost, and timeliness as three views in conflict with each other. Quality is often sacrificed to save time and costs. However, defects are not free. Someone was paid and resources were used to make the mistake (Deming 1982). Nothing saves time and money more than doing work right the first time and eliminating the need for corrective rework (Mills 1996). The goal of QC is to execute the work correctly the first time.

4 Creating a Quality Control Plan

The development of a QC plan generally takes place over a substantial period of time. During this time, the plan evolves from a list of the best practices used to control quality on the jobsite, to a systematic plan with proven policies and procedures. The main purpose of a quality manual is to provide the company with a central reference source for planning and implementing quality-related procedures (Evans 1996). Based on personal experiences, the authors feel there is a minimum of five areas that should be addressed in creating a basic jobsite QC plan. These five areas include the selection of QC personnel, management of submittals, control of materials to be used, and inspection/testing of work.

4.1 QC Personnel

The fundamental part of the QC plan concerns the people who are responsible for ensuring that work will comply with contract requirements. Each QC plan must address the desired traits of the people that will serve as the eyes and ears of the construction management team. The QC personnel, or inspectors as they are commonly known, must possess the ability to evaluate and analyze the work being inspected. This characteristic requires a degree of experience in the construction field (O'Brien 1996). QC personnel must also be able to read and interpret project plans and specifications and become familiar with provisions of the contract in order to enforce the contract requirements as written. Any work found not to be within given quality standards must be documented, tracked, and corrected. The QC plan must also delineate the lines of authority for QC personnel. One authority that must be given to QC inspectors is to allow them to stop work when there is sufficient cause to do so.

4.2 Submittal Management

The review of submittals is often an overlooked area of QC. However, managing the large amount of submittal data is another key component of the QC plan. Information received from suppliers and subcontractors must be evaluated to ascertain whether or not the intended products or methods will meet the standards set forth in the contract documents (Jenkins 1999). Often, items being submitted are substitutions of what was originally specified. Either the products are no longer available or the substituted item can be purchased for a price cheaper than the original product specified (Poles 1997c). Regardless of the reason for submission, it is of the utmost importance that each bit of submittal information be evaluated for compliance with contract requirements. This includes the verification of dimensions and compatibility with other related materials and products. Any mistakes not discovered in the submittal process can lead to future problems involving excessive time and costs due to corrective rework (Jenkins 1999). Timely submission of each submittal item and its corresponding review process should be verified against the overall project schedule to avoid any delays in construction. The scheduling of submittals must be based upon when the material or equipment is needed, and when work is to be performed per the construction schedule. Reasonable time must be allotted for submittal review/approval, procurement, fabrication, and delivery.

4.3 Verification of Incoming Materials

Verifying the conformance of delivered materials and equipment is another important function of QC personnel. Information found on delivery tickets or manufacturers' information should be compared to the data given by an approved submittal. If all information is in agreement, then the material or equipment is approved for off-loading. Care should be given to identify and dispose of non-conforming material (O'Brien 1996). Any unapproved material or equipment unloaded onto the jobsite has a chance of being included in the construction process, and lead to rework or other corrective action (Jenkins 1999). The QC plan must also ensure that the actions taken to store, handle, and clean materials and equipment are included in the plan to prevent damage and to minimize deterioration (O'Brien 1996). One must not override the storage recommendations of the manufacturer.

4.4 Inspection of Work

Inspection of work is considered to be the most important duty of inspectors. Knowing when to inspect work in-progress is beneficial to the QC person. As stated earlier, the ability to read and interpret project plans and specifications is an important characteristic of QC personnel since testing and inspection requirements are typically scattered throughout contract specifications (O'Brien 1996). Inspections can be conducted by the contractor's QC staff or by specialized individuals employed by an independent testing laboratory. Inspections must be conducted on a periodic basis to observe and review work conducted by employees of the contractor, subcontractors, vendors, and suppliers (Mahoney 1998).

The U.S. Army Corps of Engineers utilizes a formal three-phase inspection process for all definable features of work conducted on the jobsite. They are known as preparatory inspections, initial inspections, and final inspections. A definable feature of work is defined by the Corps of Engineers as any work task that is "separate and distinct from other tasks and has separate control requirements." For example, the definable features of work for concrete would be mix design, formwork, reinforcing steel, embedded items, placement method, and surface finish (USACOE 1995). Preparatory inspections, which occur prior to each new phase or type of work, include meetings that are used to review the requirements of the contract documents with the employees that will be performing the actual work. During the course of this preparatory meeting or inspection, attendees verbally build the item of work to evaluate any possible conflicts that will affect both the quality and safety of work. Corrections made at this level of inspection will cost less and will not impact the project schedule as much as if work started before the problems were discovered (Jenkins 1999).

Initial inspections take place after a representative portion of the work is complete in order to evaluate the quality of workmanship, materials, and methods used. This inspection helps verify whether or not work is starting out correctly. As with preparatory inspections, it is easier and less expensive to take corrective action as work progresses, instead of discovering defects after the work is complete (Jenkins 1999). Periodic, informal inspections are still conducted between the initial and final inspection stages. Final inspections occur after each significant portion of work is completed. This action is necessary to detect any deficient work prior to beginning the next scheduled work activity.

Another form of inspection involves specialized inspections of items that will be covered up by other materials during construction. These inspections take place prior to placing concrete, gypsum wallboard, or ceiling material. The pre-concrete pour inspection ensures that items such as reinforcing steel and other imbedded items are correctly spaced prior to placing concrete. Pre-Wallboard and Pre-Ceiling installation inspections help ensure that all plumbing, mechanical, and electrical work are in place and have been tested prior to being covered up. Centex-Rodgers, a large national constructor of hospitals, utilizes cans of spray paint for their Pre-Wallboard and Pre-Ceiling placement inspections. Each subcontractor performing work in theses areas is assigned a color of spray paint. As each subcontractor completes work in an area, he or she signals completion by marking the metal studs with their assigned color. Once all subcontractors have completed their work and marked the metal studs, Centex-Rodgers inspects the work and marks the metal studs with white spray paint. Any rooms marked with white spray paint are a signal to the drywall crews to begin hanging gypsum board in those areas.

4.5 Material/Equipment Compliance Tests

Every project owner will require the testing of material and equipment, both prior to placement and after installation. QC personnel should become familiar with the required test methods, whether or not they will be performing the actual testing. Compiling a list of the type and quantity of tests required should be created during a thorough review of the contract specifications. This checklist can then be used throughout the course of construction to ensure all required tests are conducted. Once tests have been performed, a report documenting the results should be kept for future reference (Jenkins 1999). A few of the tests typically conducted on the jobsite are listed below to illustrate the variety of testing methods used to ensure quality.

- Soils compaction tests
- Concrete slump/cylinder tests
- Ductwork leakage tests
- Hydrostatic pressure tests for pressurized piping
- Equipment performance tests

The QC plan must provide a means to obtain information regarding the many standards that govern testing requirements. It will be of great benefit to obtain this information at the beginning of the project rather than require the QC personnel to look up information on the day the particular test will be conducted. An example includes obtaining a copy of the ASTM standards used to evaluate concrete on the jobsite. ASTM C 143 governs the slump test used to determine whether or not the desired workability of the concrete has been achieved without making the concrete too wet. Meanwhile, ASTM C 470 designates the methods to cast concrete cylinders for compressive testing purposes. The value obtained from having these two standards on the jobsite will greatly benefit QC personnel when conducting an evaluation of the concrete quality, especially if they are required to conduct these tests personally.

5 Conclusion

Low-quality work and resulting customer dissatisfaction can lead to costly repair work. Creating and implementing a QC plan will help the contractor provide the project owner with a facility that meets or exceeds the quality standards required by the contract documents. By using the guidelines provided in this paper for QC personnel, submittal management, verification of incoming material, and inspection/testing of work, one can begin the process of creating such a plan. Effective use of the QC plan will help eliminate low-quality conditions and lead to fewer mistakes by ensuring that work is being performed correctly the first time. Once corrective rework is eliminated, there will be a reduced waste of project resources. As a result, lower costs, higher productivity, and increased worker morale will lead to a better competitive position for the company and aid in increasing customer goodwill.

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Factors Affecting Safety on Construction Projects

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Abstract

The construction industry is concurrently recognized as a major economic force and one of the most hazardous industries. Accidents not only result in considerable pain and suffering but marginalize productivity, quality, time, and negatively affect the environment and consequently add to the cost of construction. Unfortunately, safety and health (S&H) and the environment are often neglected on construction sites and rarely managed. Safety and health is often discussed in management meetings as a priority, while in reality safety and health takes a low priority to budget and time discussions. S&H is being identified as a parameter that should be used along with the traditional parameters: cost, quality and time, to measure the success of projects. An effective safety program may prevent many accidents on construction sites. The reasons for considering safety and health are: human factor, legislation and financial issues. Inadequate safety and health has a negative impact on both the construction and built environments resulting in fatalities, injuries and diseases. The aim of this paper is to discuss the factors influencing safety on construction projects in Palestine. The study concludes that the benefits of S&H improvements include: reduced accident costs, increased productivity, improved human relations and enhanced firms' image. S&H should be considered as a prerequisite for productivity and quality. It is recommended that management should give full safety training to all employees; good training of site managers and operatives can lead to improved safety on site.

Keywords

Safety, health, cost, environment, construction.

1 Introduction

Accidents at work occur either due to lack of knowledge or training, a lack of supervision or a lack of means to carry out the task safely, or due to an error of judgment and carelessness. In addition to these factors, the short term and transitory nature of the construction industry, the lack of controlled working environment and the complexity and diversity of the size of construction firms, all have an effect on construction projects' safety. In construction and building projects, unsafe behavior is considered to be the most significant factor in the cause of site accidents and therefore provides evidence of a poor safety culture.

Traditionally, cost, quality and time have constituted the parameters within which projects have been procured and managed. However, cost quality and time can be indirectly compromised by lack of safety and health, or directly as a result of accidents. There are three reasons for considering safety and health in construction industry, these are: human factor, legislation and financial issues. Environmental concerns are often interrelated with construction health and safety issues (Coble and Kibert, 1994). Unhealthy and unsafe practices, inter alia, concrete run-off or spillage, fires, oil spillage, waste and uncontrolled sanitation impact negatively on the environment. Generation of dust, hazardous materials and the release of non-biodegradable material into the environment contribute to the impact (Smallwood, 1998).

Health and safety is vitally important, not just cost, quality and time because if a worker has been permanently disabled or killed, then a project is not a success (Hinze, 1997). Hinze maintains outstanding projects are: either a head or on schedule, within budget and reflect exemplary S&H. Total quality includes health and safety and all requirements are achievable concurrently. Levitt and Samelson (1995) stated that quality includes productivity and health and safety. The objective of this paper is to study the factors affecting safety and health on construction projects.

2 The cost of accidents

The cost of accidents can be categorized as being either direct or indirect costs. The direct costs of injuries are those that are most visible and are typically referred to as insurable costs. Direct costs may include: medical cost, premiums for compensation benefits, liability, and property losses. The direct costs can generally be quantified with reasonable accuracy. Indirect costs of accidents are more difficult to measure. Indirect costs are essentially all non-insurable costs incurred as a result of an injury. The indirect costs are those which are hidden and for which no historical record is kept.

Indirect costs include: reduced productivity for both the returned workers and the crew or workforce, clean-up costs, replacement costs, stand-by costs, cost of overtime, administrative costs, replacement worker orientation, costs resulting from delays, supervision costs, costs related to rescheduling, transportation, and wages paid while the injured is idle (Hinze, 1994; Smallwood, 1998). Heinrich (1959) identified indirect costs associated with accidents as:

- Cost of lost time of injured employee.
- Cost of work stoppage of other employees.
- Lost supervisory time.
- Cost of time spent on the case by first-aid attendant.
- Cost of damage to the machinery tools, or other property.

Although Heinrich study was related to manufacturing, it describes many of the indirect costs of a construction project accident. Indirect costs are generally several times larger than the direct costs associated with an accident. Studies have shown that the ratio of indirect costs to the direct costs can range from 4 to 1 up to 7 to 1 (Robinson, 1979). It is possible that these ratios are based on incomplete data and therefore the economic impact is underestimated.

Heinrich conducted a study of a large number of injuries and concluded that the indirect costs of injuries were approximately four times the direct costs (Heinrich, 1959). The safety profession appears to have embraced the ratio of four to one, which Heinrich postulated. However, this ratio of indirect to direct costs is not universally accepted in the construction industry. Another study indicated that the ratio of indirect to direct costs for medical-case injuries is 4 to 2 and for restricted activity or lost-workday injuries is 20 to 3 (Hinze and Appelgate, 1992). These ratios are extremely variable with injury severity being a primary influence on their magnitude.

3 Safety management

Safety is an economic as well as humanitarian concern that requires proper management control. Benefits of safety and health may include: less injuries, less property damage, less down time, improvement in morale, enhance industrial relations, increased productivity, reduced cost and enhanced quality (Promfret, 1997). Other benefits include: less compensation insurance, fewer hidden costs, improved supervisor morale, increased efficiency, and improved marketability (Levitt and Samelson, 1995).

Most accidents on construction sites are preventable through implementation of an effective safety program. Unsafe conditions and accidents are usually a sign that something is wrong in the management system. Safety and health must be managed in the same manner that other aspects of a company are managed (Peterson, 1979). Although an effective safety program can prevent or reduce injuries, not all contracting organizations implement safety programs.

Hinze and Parker (1978) stated that good safety performance and high productivity are compatible and that safety should not be sacrificed in an endeavour to enhance productivity. Good safety performance is also related to the management style and that applying excessive pressure by any means to the workmen resulted in increased injuries. The productivity of crews may be adversely impacted by a worker injury. For instance, a crew working in the vicinity of the accident will probably work less productively as a result of the injury. Initially, these crews may simply stop work in order to observe the activities surrounding an injury. The crews may be less productive because of discussions with fellow workers concerning the accident.

4 Research methodology

This research commenced by reviewing the relevant literature on construction health and safety. This was followed by exploratory interviews with five construction managers. The interview discussions were focused on the importance of health and safety, benefits of health and safety improvement, tendering system and safety, and factors affecting safety on construction projects. The outcome of the exploratory interviews has prepared the way for the main study. Thirty two construction managers were interviewed in this study. List of names and addresses were obtained from personal contacts.

5 Results

The results indicated that the majority of construction managers viewed safety and health to be important (Table 1). It has been observed that tidy sites may minimize accidents and provide a high level of safety performance.

Table 1: Importance of safety and health

Importance of safety and Health	Response (%)
Very important	45.3
Important	41.7
Fairly important	9.9
Not important	3.1
Total	**100.0**

The respondents stated that the benefits of S&H improvement were: reduced accident costs, increased productivity, improved human relations, and enhanced firms image (Table 2).

Table 2: Benefits of safety and health improvement.

Nature of improvement	Response (%)
Reduced accident costs	52.1
Increased productivity	34.8
Improved human relations	17.3
Raise firms image	14.9
Others	11.3

The results showed that 92.8% of respondents indicated that S&H process is negatively affected by competitive tendering. The construction managers mentioned that committed contractors who make an adequate allowance for safety and health may run the risk of losing the tender to a contractor who is less committed to safety and health. Owners did not consider pre-qualification of contractors on S&H.

It has been observed that there is a close relationship between the age and experience of operatives and their level of safety awareness. Operatives between 16-22 were found to be more subjected to accidents than others. The level of accidents tends to decline after the age of 30. This result suggests that the older the operative gets the more experienced he becomes, hence more aware of safety requirements. The results showed that management was more concerned with the problem of productivity rather than safety and health issue. Productivity bonuses as an incentive for higher productivity were paid without due regard to safety. Management was not concerned with safety bonuses.

Scaffolding was found to be a great source of accidents on construction site. 91.2% of the respondents believed that certain criteria such as good technical skill, training and experience should be considered as highly important to certify those who handle scaffolding. A large number of operatives work on construction sites without adequate training. Construction managers stated that workers are reluctant to wear safety protective clothing. This is strongly related to operatives' personal attitudes towards safety protective clothing and equipment. This study indicated that management did not give enough importance to the training of operatives on how and where to use protective safety equipment and clothing.

6 Conclusions

This study demonstrates the importance of safety and health in construction and highlights the factors affecting safety on construction projects. The benefits of safety and health improvement include: reduced accident costs, increased productivity, improved human relations and enhanced firms image. Age and experience have an impact on the level of safety on construction sites. Safety and health should be included as a project parameter, which means it should be considered during all phases of a project.

Safety and health should be considered as a prerequisite for productivity and quality. Accidents result in increased project costs and human suffering. Legislation should be evolved that engenders prioritization of health and safety by all stakeholders. Procurement systems should be evaluated in terms of their impact on safety and health prior to their selection for projects. Prospective contractors should not be placed on tender lists unless they can show competence in the management of safety and health.

The management of safety and health should be an integral part of the management process. Developing the safety program and policies for contract document requirements should be a responsibility of the design team during the design phase. The contract documents should clearly indicate special safety provisions and identify the authority of personnel relative to safety. Managers need to give full safety training to all employees; good training of site managers and operatives can lead to improved safety on site.

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The role of project managers in construction quality

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Abstract

Project managers (PMs), in their capacity as lead consultant, are in a unique position to positively influence quality. This is due to their interface with the client, coordination of the various design contributions, the coordination of design and construction, and the supervision of construction.

The paper reports on an aspect of a study conducted among construction PMs to determine their influence on occupational health and safety, labour productivity, and quality in South African construction. Selected findings are as follows.

Project quality is ranked second after client satisfaction in terms of the degree of importance of eleven project parameters. A minimal percentage of practices use quality assurance mechanisms to assure the achievement of quality, site supervision predominating. Site inspections / discussions and site meetings predominate in terms of the occasions practices consider or refer to quality, whereas specification and finishes predominate in terms of various aspects considered or referred to. According to the majority of practices clients often revise requirements and need to issue variation orders. Designer prioritization / consideration of quality, pre-qualification of contractors on quality, and contract documentation predominate among aspects and interventions, which could contribute to an improvement in quality. Project programme achieved a ranking of first among eight aspects in terms of the negative impact of rework. It can generally be concluded that PMs consider and refer to construction quality more frequently during construction, than procurement and design related occasions.

Keywords

Project managers, design, construction, quality

1 Introduction

Quality has traditionally constituted a project performance criterion, which impacts on project stakeholders' satisfaction. The achievement of quality is critical as the non-achievement thereof results in rework, and client, designer, contractor and even worker dissatisfaction. It also results in variability of resources used, which increases project risk (Smallwood and Rwelamila, 1996).

Aspects of project management occur upstream of construction, and PMs often advise clients regarding the type of construction procurement system to adopt. They also fulfill the function of principal agent and coordinate design, and supervise construction. Project quality management is one of nine project management knowledge areas and the Project Management Institute (PMI) (1996) identifies quality planning, quality assurance, and quality control as the major project quality management processes.

Given the documented impact of rework, the influence of rework on other project parameters, the need for a multi-stakeholder approach to quality, and the unique position and role of PMs in projects, a study was conducted, the objectives relative to quality, and specifically the influence of design, were to determine:

- The importance of various project performance criteria;
- Practices adopted to achieve quality;
- Frequency of consideration of and reference to quality throughout the project phases;
- Frequency of consideration of and reference to quality relative to various design aspects;
- Frequency at which various procurement and construction situations which affect quality are encountered;
- The aspects and actions which can improve or contribute to an improvement in quality, and
- The impact of rework on other project parameters and project risk.

Given that projects are unique and involve a certain degree of risk the Project Management Body of Knowledge (PMBOK) recommends that projects be subdivided into several phases to provide for better management control. These phases which are collectively referred to as the project life cycle are: concept and initiation; design and development; implementation or construction, and commissioning and handover (PMI, 1996). The paper only addresses the second and third phases, namely design and development, and implementation or construction, hereafter referred to as design and construction for reasons of brevity.

2 Literature Survey

2.1 Quality

Crosby (1984) defines quality as “conformance to requirements.” Conformance to requirements (26.8%), excellence (26.1%), conformance to customer requirements (18.3%) and customer satisfaction (13.4%) predominated among definitions of quality selected by general contractors (GCs) during research conducted in South Africa (Rwelamila and Smallwood, 1998). Collectively the ‘conformance related’ definitions attracted 45.1% of the GCs’ responses.

2.2 The need for quality

Non-conformance to requirements invariably results in rework – work required beyond that initially required and / or envisaged to conform to requirements. According to the Associated General Contractors of America (AGC) (1992) research conducted in the USA on nine industrial projects determined the average cost of rework to be 12.4%, and normal work to be 87.2% of project cost. The 12.4% was constituted as follows: client changes (3.3%); design errors (3.3%); construction errors (2.8%), and other (3%). Research conducted among GCs in South Africa determined rework to constitute on average, 13% of the value of completed construction (Smallwood and Rwelamila, 1996).

Further research conducted in South Africa by Rwelamila and Smallwood (1998) determined that cost (75.8%), client satisfaction (71.2%), future work (62.7%) and productivity (62.7%) predominated among aspects negatively affected by the non-achievement of quality.

2.3 Role of project managers

The Chartered Institute of Building (CIOB) (2002) states that it is the PM's role to set up and implement an appropriate process to manage project quality. The quality policy should be defined during the project brief. A quality strategy should then be evolved, followed by a quality plan, which sets out the parameters for the designers and the appointment of contractors. Thereafter quality control becomes the responsibility of the contractor, the subcontractors and suppliers operating within the quality plan (CIOB). According to Griffith (1990) the structure and organisation of a project management approach lends itself to the requirements of QA. Project management provides a single interface between clients and the respective designers, which engenders finalisation of clients' requirements and the integration of design.

The PMBOK identifies quality planning, quality assurance, and quality control as the major project quality management processes (PMI, 1996). The three processes can each be reviewed in terms of inputs, tools and techniques, and outputs.

2.4 Role of design

Griffith (1990) maintains quality of the design process indicates reliability of the design, details and specification, and reliability of the information that has been used as the basis for the design and product specification.

2.5 Causes of rework

A survey conducted by the Building Research Establishment (BRE) in the United Kingdom indicates that 40% of building defects occur during the construction phase, as a result of on-site practice, whilst 10% are due to product failure, and 50% can be attributed to design – most of the 'design' defects were the result of either poor technical detailing or the oversight of specific requirements (Lam, Low and Teng, 1994).

Griffith (1990) cites problems attributable to design as: inaccurate or inadequate detail; incorrectly specified or inappropriate materials and components; inadequate knowledge of or disregard for legislation or guidelines; co-ordination: inadequate coordination between client / designer, designers, and designers / contractors; poor interaction between client / designer, and designers / contractors; inadequate supervision by designers, and lack of design empathy for construction.

According to Chung (1999), in most cases defects are found to be the result of: misinterpretation of drawings and specifications; use of superceded drawings and specifications; poor communication with the architect / engineer, subcontractors and material suppliers; poor coordination of subcontracted work; ambiguous instructions or unqualified operators / workers, and inadequate supervision and verification on site.

2.6 Achieving quality

International literature indicates that control related actions / interventions predominate. Landin (1995) maintains inspection is the most common way of achieving quality, even though it occurs downstream. However, visual checks are not the preferred intervention, as invariably they occur after a non-conformance has occurred.

Documented QMSs are fundamental to the systematic management of quality as they result in a structured approach, and provide the framework for quality assurance and the basis for quality improvement. A documented QMS enables the main areas of concern in a QMS to be dealt with: control and maintenance of the quality system; control functions to eradicate quality deficiencies; feedback to ensure both effective operation and that controls are being achieved, and review of the declared quality system to ensure that it reflects policy (Smallwood and Rwelamila, 1998).

McGeorge and Palmer (2002) stress the role of constructability and cite the sixteen design for constructability principles listed by Adams and Ferguson, eight of which are quality related: use suitable materials; design for the skills available; design for simple assembly; plan for maximum repetition / standardization; allow for sensible tolerances; allow for practical sequences of operations; plan to avoid damage to work by subsequent operations, and communicate clearly.

2.7 Barriers to achieving and improving quality

Based upon research conducted among architectural practices and GCs in South Africa, Alman (1989) says the following act as barriers to the achievement of quality: the dominant use of the traditional construction procurement system (TCPS); contractors competing primarily on cost; short contract durations; separation of design and construction; intricate and impractical details; poor design coordination, and unrealistic specifications.

Griffith (1990) maintains the TCPS, where design is separated from construction, and each designer acts independently, presents distinct problems for the implementation of QA. The problems arise through the multiplicity of design and production responsibilities involved in the constructed form and moreover, from the lack of integration which occurs through the traditional separation of the various parties.

Research conducted among GCs (Smallwood and Rwelamila, 1996) determined that many of the procurement related barriers to achieving and / or improving quality cited in literature, prevailed in South African construction. These are: design is not complete before selecting a contractor; architects are not always able to coordinate and supervise the design team; contractors are selected predominantly on price; design is separated from construction, and contractors' expertise is not included in design.

2.8 Improving quality

Griffith (1990) maintains a pre-requisite is to adopt a quality assurance (QA) approach. Given that a substantial percentage of defects can be traced back to design, Lam et al. (1994) advocate QMS certification of designers as an action to engender ‘defect-free’ design and detailing.

The integration of design and construction is frequently cited as it facilitates, inter alia, contractor contributions to improving design, enhanced consideration for the construction process during design, and feedback. Appropriate procurement systems that enhance the integration of design and construction, such as design-build, are credited with having contributed to improving quality (Griffith, 1990).

Based upon the research conducted among architectural practices and GCs in South Africa Alman (1989) recommends the following actions: partnering; realistic project durations; practical specifications; pre-qualification of contractors on quality; management commitment; implementation of quality programmes, and education and training in quality. Partnering brings the various stakeholders involved in a project together to, inter alia, develop mutual goals and mechanisms for solving problems (AGC, 1991). Project durations that are compatible with the nature and scope of the work are important, as 65.8% of GCs surveyed in South Africa responded that shortened project period negatively affected quality. Pre-qualification in turn, facilitates the selection of contractors on the basis of commitment to the assurance of quality (Smallwood and Rwelamila, 1996).

Project management, which realises a single interface between the client and design team, can promote the achievement of quality, as a project management structure separates management from the design and construction processes leaving the designers “free to concentrate on the aspect of the project about which they know best.” The project management team then provides the integrating communication, co-ordination and control functions, focusing upon the three traditional project parameters of cost, quality and schedule (Griffith, 1990).

3 Research

3.1 Sample frame

The sample frame consisted of construction PMs, which were members of the Project Management Institute of South Africa (PMISA). 489 questionnaires were mailed by the PMISA on behalf of the researcher to assure confidentiality of PMISA’s membership directory. 30 responses were included in the analysis of the data, which constitutes a response rate of 6.2 % (30 / 487) – two questionnaires did not satisfy the criteria for inclusion. It is significant to note that the total membership of the more recently established Association of Construction Project Managers (ACPM) is approximately 100 i.e. the actual sample frame was probably in the region of 100 as opposed to 489.

3.2 Analysis

Given that respondents were required to respond in terms of frequency and importance, it was necessary to compute an importance index (II) with a minimum value of 0, and a maximum value of 3 or 4, to enable a comparison of, and to rank various aspects / actions, parameters, occasions, and situations / interventions. The (II) is calculated using the formulae:

$$\frac{4n_1 + 3n_2 + 2n_3 + 1n_4 + 0n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)} \quad \text{or} \quad \frac{3n_1 + 2n_2 + 1n_3 + 0n_4}{(n_1 + n_2 + n_3 + n_4)}$$

where
n_1 = Very important/Always
n_2 = Important/Often
n_3 = Neutral/Sometimes
n_4 = Not really important / Rarely
n_5 = Not important/Never and Don't know

where
n_1 = Very Important/Often
n_2 = Important/Sometimes
n_3 = Fairly important/Rarely
n_4 = Not important and Unsure / Never and Don't know

3.3 Findings

The PMs worked for practices:

- which on average employed 5.7 persons;
- the greater percentage (36.7%) of which project managed projects with a total value of more than R 100m per annum;
- which on average were principal agent on 77.7% of projects they provided project management services for;
- which were predominantly involved with infrastructure (39%) and industrial (30%) type projects, and
- which were exposed to all 'height level' categories.

Respondents were asked to rate the importance of construction H&S, labour productivity, and quality on a scale of 'very important to not important', to enable the computation of an II with a minimum value of 0.0, and a maximum value of 3.0. Quality (2.73) achieved a ranking of 1st, followed by H&S (2.45) and labour productivity (2.43), which indicates that they can all be deemed to be important.

Respondents were also asked to rate eleven project parameters on a scale of 1 (very important) to 5 (not important) to enable the computation of an II with a minimum value of 0.0 and a maximum value of 4.0. It is significant that the values of all the IIs are above the midpoint value of 2.0, which indicates that all the project parameters can be deemed to be perceived as important to PMs. Client satisfaction achieved a ranking of first, followed by the traditional project parameters of quality, cost and time. Client satisfaction is a holistic state and is a function of, inter alia project quality. Project H&S achieved a ranking of fifth. It is also significant that the II values of the top five ranked project parameters are above 3.2, which indicates that these project parameters can be deemed to be perceived as between more than important to very important / very important.

Table 1 presents the frequencies at which PMs consider or refer to construction quality on various occasions in terms of the frequency range: never; rarely; sometimes; often, and always. The fourteen occasions are ranked based upon an II with a minimum value of 0.0. and a maximum value of 4.0. It is significant that the values of all the IIs are above the midpoint value of 2.0, which indicates that the consideration of or reference to construction quality on various occasions can be deemed to be prevalent. It is also significant that the II values of the top eleven ranked occasions are $> 3.2 \leq 4.0$, which indicates that construction quality is considered or referred to between often and always / always on these occasions. Site meetings achieved a ranking of first, and predominate along with site inspections / discussions, and prequalifying contractors. It is notable that the top two occasions are 'downstream' oriented. However, the occasions ranked third and fourth are 'upstream' oriented. Given that only two of the fourteen occasions are 'downstream', these findings are more significant than notable.

Table 1: Frequency at which PMs consider / refer to construction quality.

Occasion	Frequency (%)						II	Rank
	Don't know	Never	Rarely	Some-times	Often	Always		
Site meetings	0.0	0.0	0.0	0.0	26.7	63.3	3.70	1
Site inspections/ discussions	0.0	0.0	0.0	3.3	23.3	66.7	3.68	2
Pre-qualifying contractors	0.0	0.0	0.0	3.3	30.0	60.0	3.61	3
Evaluating tenders	0.0	0.0	0.0	10.0	26.7	56.7	3.50	4=
Site handover	0.0	0.0	3.3	3.3	30.0	56.7	3.50	4=
Preparing project documentation	0.0	0.0	3.3	6.7	23.3	60.0	3.50	4=
Client meetings	0.0	0.0	0.0	10.0	30.0	53.3	3.46	7
Detailed design	0.0	0.0	6.7	3.3	26.7	56.7	3.43	8
Design coordination meetings	0.0	0.0	6.7	3.3	26.7	53.3	3.41	9
Pre-tender meeting	0.0	0.0	3.3	10.0	30.0	50.0	3.36	10
Working drawings	0.0	3.3	3.3	13.3	20.0	53.3	3.25	11
Constructability reviews	0.0	0.0	6.7	16.7	23.3	46.7	3.18	12
Concept (design)	0.0	0.0	6.7	20.0	26.7	40.0	3.07	13
Deliberating project duration	0.0	3.3	10.0	23.3	26.7	30.0	2.75	14

Table 2 presents the frequencies at which PMs consider / refer to construction quality relative to various design related aspects in terms of the frequency range: never; rarely; sometimes; often, and always. The sixteen aspects are ranked based upon an II with a minimum value of 0.0 and a maximum value of 4.0. It is significant that the values of all the IIs are above the midpoint value of 2.0, which indicates that the consideration of or reference to construction quality relative to various design related aspects can be deemed to be prevalent. It is also significant that the top five ranked design related aspects had II values $> 3.2 \leq 4.0$, which indicates that construction quality is referred to relative thereto between often to always / always. Type of structural frame and method of fixing achieved rankings of second and third respectively, followed closely by position of components and design (general). Given that certain materials contain hazardous chemical substances (HCSs) it is notable that content of material achieved a ranking of sixth. Given that materials handling, and more specifically the mass of materials contribute to manual materials handling, it is also notable that mass, edge, texture and surface area of materials achieved rankings from thirteenth to sixteenth respectively. However, finishes and schedule, which encapsulate materials and processes, achieved rankings of eleventh and twelfth respectively. Plan layout, site location, elevations and details achieved II values of 2.62 and higher.

Table 2: Frequency at which PMs consider / refer to construction quality relative to various design related aspects.

Occasion	Frequency (%)						II	Rank
	Don't know	Never	Rarely	Some-times	Often	Always		
Specification	0.0	0.0	0.0	10.0	33.3	56.7	3.47	1
Finishes	0.0	0.0	0.0	16.7	26.7	56.7	3.40	2
Schedule	0.0	3.3	3.3	6.7	33.3	53.3	3.30	3
Method of fixing	0.0	0.0	0.0	16.7	36.7	43.3	3.28	4
Design (general)	0.0	3.3	0.0	16.7	30.0	50.0	3.23	5
Details	0.0	0.0	3.3	16.7	40.0	40.0	3.17	6
Position of components	0.0	3.3	0.0	16.7	36.7	36.7	3.11	7
Content of Material	0.0	6.7	6.7	6.7	26.7	50.0	3.10	8
Type of structural frame	0.0	6.7	0.0	16.7	33.3	43.3	3.07	9
Plan layout	0.0	6.7	6.7	20.0	30.0	36.7	2.83	10
Elevations	0.0	6.7	10.0	16.7	30.0	36.7	2.80	11
Surface area of materials	3.3	6.7	6.7	10.0	36.7	33.3	2.79	12
Mass of materials	0.0	10.0	6.7	23.3	26.7	33.3	2.67	13
Site location	0.0	6.7	6.7	26.7	33.3	23.3	2.62	14
Texture of materials	3.3	6.7	6.7	26.7	20.0	26.7	2.52	15
Edge of materials	6.7	10.0	3.3	23.3	23.3	30.0	2.48	16

Table 3 prevents the frequencies at which PMs achieve / encounter / use various procurement related situations / interventions in terms of the frequency range: never; rarely; sometimes, and often. The eight aspects are ranked based upon an II with a maximum value of 3.0 and a minimum value of 0.0. It is significant that the values of all the IIs are above the midpoint value of 1.5, which indicates that the achieving / encountering / use of the situations / interventions can be deemed to be prevalent. It is also significant that the top four ranked situations / interventions are cited by literature as having a negative influence on construction quality: clients revise their requirements; competitive tendering, drawings are revised, and variation orders. Similarly, with respect to the sixth ranked situation, design is separated from construction. Although the situations / interventions which complement construction quality achieved rankings of fifth, seventh and eighth, namely, optimum project period, prequalification of contractors, and design is complete when construction commences, their II values are all above the midpoint value of 1.50.

Table 3: Frequency at which PMs achieve / encounter / use various procurement related situations / interventions.

Situation / Intervention	Frequency (%)					II	Rank
	Don't know	Never	Rarely	Some-times	Often		
Clients revise their requirements	0.0	0.0	0.0	16.7	83.3	2.83	1=
Competitive tendering	0.0	0.0	0.0	16.7	83.3	2.83	1=
Drawings are revised	0.0	0.0	3.3	23.3	73.3	2.70	3
Variation orders	0.0	0.0	10.0	20.0	70.0	2.60	4
Optimum project period	0.0	0.0	16.7	23.3	60.0	2.43	5
Design is separated from construction	0.0	6.7	13.3	33.3	46.7	2.20	6
Prequalification of contractors	0.0	3.3	16.7	46.7	33.3	2.10	7
Design is complete when construction commences	0.0	10.0	30.0	23.3	36.7	1.87	8

Table 4 indicates the extent to which PMs perceive various aspects / actions can contribute to an improvement in construction quality. Respondents could respond relative to 'unsure', 'no', and 'yes', as opposed to scaled responses. With the exception of prequalification of contractors on H&S, and partnering, the majority of PMs responded in the affirmative to the various aspects / actions.

Project programme (96.7%), cost of construction (90%), and labour productivity (90%) predominate among other project parameters negatively affected by rework. However, the majority (66.7%) also identified client satisfaction, and between 40 % and 50 % H&S and quality.

93.3 % of PMs responded that rework increases overall project risk.

Table 4: Extent to which aspects / actions can contribute to an improvement in construction quality.

Aspect / Action	Response (%)			
	No response	Unsure	No	Yes
Project specific plan for quality	0.0	0.0	0.0	100.0
Pre-qualification of contractors on quality	0.0	3.3	3.3	93.3
Quality Management System	3.3	0.0	3.3	93.3
Project specific plan for H&S, and quality	3.3	3.3	0.0	93.3
Designer prioritisation/consideration	3.3	6.7	0.0	90.0
Constructability reviews by designers	10.0	3.3	0.0	86.7
Contractor programming	0.0	6.7	6.7	86.7
Contract documentation	3.3	0.0	16.7	80.0
Client actions	0.0	6.7	13.3	80.0
Optimum project programme	3.3	13.3	10.0	73.3
Choice of procurement system	3.3	16.7	13.3	66.7
Pre-qualification of contractors on H&S	0.0	16.7	23.3	60.0
Partnering	3.3	20.0	20.0	56.7

4 Conclusions

The conclusions, based upon the literature and descriptive surveys, have been presented relative to the objectives of the study.

4.1 The importance of construction quality and other project parameters to PMs

The descriptive survey reflects the findings of literature, namely that quality, cost and time are the 'most important' parameters. Although these parameters achieved rankings of second, third and fourth, the first ranked client satisfaction is a function of satisfactory performance relative to quality, cost and time. However, the values of all the IIs for the parameters are above the midpoint value of 2.0, which indicates that they can be deemed to be important to PMs.

Relative to this objective it can be concluded that PMs prioritise the traditional project parameters of cost, quality and time.

4.2 The frequency at which PMs consider and, or refer to construction quality during the design and construction phases

Given that the values of the IIs for all the occasions were above the midpoint value of 2.0, it can be concluded that construction quality can be deemed to be considered and, or referred to by PMs on all occasions. It is significant that the top two ranked occasions are both construction related, namely site meetings, and site inspections / discussions, which indicates a preference by PMs to address construction quality during construction.

The third ranking achieved by pre-qualifying contractors, and the joint fourth ranking of evaluating tenders and preparing project documentation indicate an appreciation for the role of procurement related interventions in construction quality.

Relative to this objective, it can generally be concluded that PMs consider and refer to construction quality more frequently during construction, than procurement and design related occasions - the top ranked design occasion, detailed design, achieved a ranking of eighth. However, given that the three highest ranked design related occasions have II values > 3.2 i.e. construction quality is considered / referred to between often and always / always, it can be concluded that PMs appreciate the role of design in construction quality.

4.3 The frequency at which PMs consider and, or refer to construction quality relative to various design related activities

Given that the values of the IIs for all the various design related activities were above the midpoint value of 2.0, it can be concluded that construction quality can be deemed to be considered and, or referred to by PMs during all the design related activities. Specification finishes, schedule, method of fixing, and design (general) predominates.

4.4 The frequency at which various procurement related situations or interventions, which affect construction quality, are encountered or taken by PMs respectively

Given that the II values for all the various procurement related situations and interventions are above the midpoint value of 1.5, it can be concluded that the situations or interventions are encountered or taken by PMs.

Relative to this objective it can be generally concluded that situations or interventions, which negatively affect construction quality, are encountered or taken more frequently than those that positively affect construction quality. The former being: clients revise their requirements; competitive tendering; drawings are revised, and variation orders. The latter being: optimum project period; prequalification of contractors, and design is complete when construction commences.

4.5 The aspects or actions, which PMs perceive can improve or contribute to an improvement in construction quality

The majority of PMs identified eleven out of thirteen aspects / actions identified in literature as having the potential to improve, or contribute to an improvement in project quality.

Three of the top four ranked aspects or actions clearly indicate the importance of planning, namely: project specific plan for quality; QMS, and project specific plan for H&S, and quality. The level of affirmative response relative to a most aspects / actions clearly indicates the need for multi – stakeholder contributions to construction quality by clients, PMs, designers, and contractors. The level of affirmative response relative to designer prioritization / consideration, and constructability reviews by designers, amplify the role of design, and the need for PMs to ensure it.

Relative to this objective, it can generally be concluded that various design, procurement and construction related aspects and actions have the potential to improve or contribute to an improvement in construction quality.

4.6 The perceived impact of rework on other project parameters and project risk

Although PMs appreciate the extent to which rework negatively affects project programme, cost of construction, labour productivity, and client satisfaction, they do not do so relative to the other project parameters, in particular, quality. Despite the latter status quo, PMs do appreciate that rework increases overall project risk.

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D^4h – Influences on Designing for Health

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Abstract

D^4h is a two-year UK Government-funded research project developing a strategy for best practice in designing construction projects to account for the occupational health of construction workers. For many years, health has been the 'poor relative' of safety in 'health and safety' considerations. This is an important issue where little in-depth work exists although it is rapidly becoming a key issue for many European countries. The European Temporary and Mobile Construction Sites Directive, leading to CDM in the UK, has stimulated a change in design culture in many states with designers being expected to explicitly acknowledge health and safety in their designs and seek to reduce or remove risk to construction workers. However, all the concentration so far has been on safety, to the exclusion of occupational health, except for issues surrounding hazardous substances. This paper presents the preliminary findings from the first phase of the D^4h project, namely semi-structured interviews of experienced design practitioners and managers regarding design phase provision for occupational health of construction workers. The intention of this paper will be to raise the principal issues regarding design influences and provide a platform for further debate.

Keywords

European TMCS Directive, CDM, Healthy Design, Risk Assessment

1 Introduction

The Construction (Design and Management) Regulations (CDM) were introduced in the UK in March 1995, derived from the European Directive on Temporary and Mobile Construction Sites (92/57/EEC). This directive has been dealt with at length in as can be seen in the CIB conference proceedings, Safety Co-ordination and Quality in Construction (1999) which contains reports from throughout Europe on implementation of the Directive. Smallwood et al (2000) stress that ‘design precedes construction and consequently designers have the greatest potential in terms of contributing to the minimising and/or eliminating of the risk posed by hazardous chemical substances’. Duff & Suraji (2000) also explain that the design role is ‘not only associated with providing better design outputs but also minimising negative effects of the design process and maximising the value of their design skills and project knowledge’.

‘Health and Safety is often used by experts and non-experts alike to represent only safety. Most health and safety managers, supervisors or inspectors have little more than a very rudimentary knowledge of occupational health issues’ (Gibb, 2002). The authors argue that this is also true of designers. Every year many thousands of construction workers suffer from work-related ill health. In 1995, the UK’s self-reported work-related illness survey found an estimated 134,000 construction-related workers report a health problem caused by their work, resulting in an estimated 1.2 million days lost in a workforce of 1.5 million (Gibb 2002). In particular there were 96,000 musculoskeletal disorder cases; 15,000 respiratory disease cases; 6,000 cases of skin disease and 5,000 noise induced hearing loss cases. Hand arm vibration syndrome (HAVS) has also been identified as a health hazard as shown by recent research (Gibb 2002).

The European Construction Institute (ECI) produced a guide to managing health in construction (ECI 1999). It includes strategies to manage health throughout the construction process and gives information on regulations for health issues in European countries. This manual is mainly targeted at construction managers, so the D^4h project is applying some of this previous work and develop practical guides for designers. The overall strategy of D^4h is to identify and build on current ‘best practice’ where it exists for healthy design, particularly issues relating to the construction process. Currently, little exists which can be used as a benchmark and there is little specific guidance for healthy design.

2 Methodology

This paper presents the preliminary findings from the first phase of D^4h, namely interviews of experienced design practitioners and managers regarding design phase provision for occupational health of construction workers. A 19 question semi-structured interview was developed and piloted. In addition to some closed questions to gather comparative data, many of the questions were open-ended to allow discussion to evolve and it is these questions that form the basis of this paper. Individuals were asked to give their own opinion, not just that of company policy. Interviewees were designers selected from individuals linked to the project steering group, the ECI and other design experts employed in the construction sector. 14 individuals were interviewed, from various construction sectors including petrochemical, architectural, and design contractors. The interviewees are described in Table 1.

Table 1. Background data on interviewees

Interviewee Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specialist Area														Data unavailable
Architect	X				X			X	X					
Structural Engineer		X												
H&S/CDM Manager			X				X							
Civil Group Manager				X										
Design/Technical Manager						X				X	X		X	
Head of Support												X		
Years Experience														Data unavailable
0-10		X												
11-15			X					X					X	
16 - 20				X						X	X			
21-25						X	X							
26-30	X								X			X		
30+					X									
Gender														
Male	X			X	X	X	X	X	X	X	X	X	X	X
Female		X	X											
Project Types														Data unavailable
Petrochemical/Power				X										
Residential			X				X	X	X		X			
Civil	X		X							X		X	X	
Commercial	X	X	X			X	X	X	X					
Retail	X	X	X			X	X	X						
Educational	X		X				X	X						
Recreational	X		X			X	X	X	X					
Light Industrial	X	X	X		X	X	X	X	X					
Pharmaceutical				X	X							X		
Airports											X			

3 Results and Discussion

3.1 Healthy Design Procedures

The basis of the procedures used for designing for healthy construction varied significantly across the interviewee's organisations. It was difficult in most of the interviews to separate out occupational health issues from the overall health and safety issues. Several of the companies had extensive documents outlining guidance for designers that incorporated CDM requirements. Figure 1 illustrates the influences on design to take account of the occupational health of construction workers.

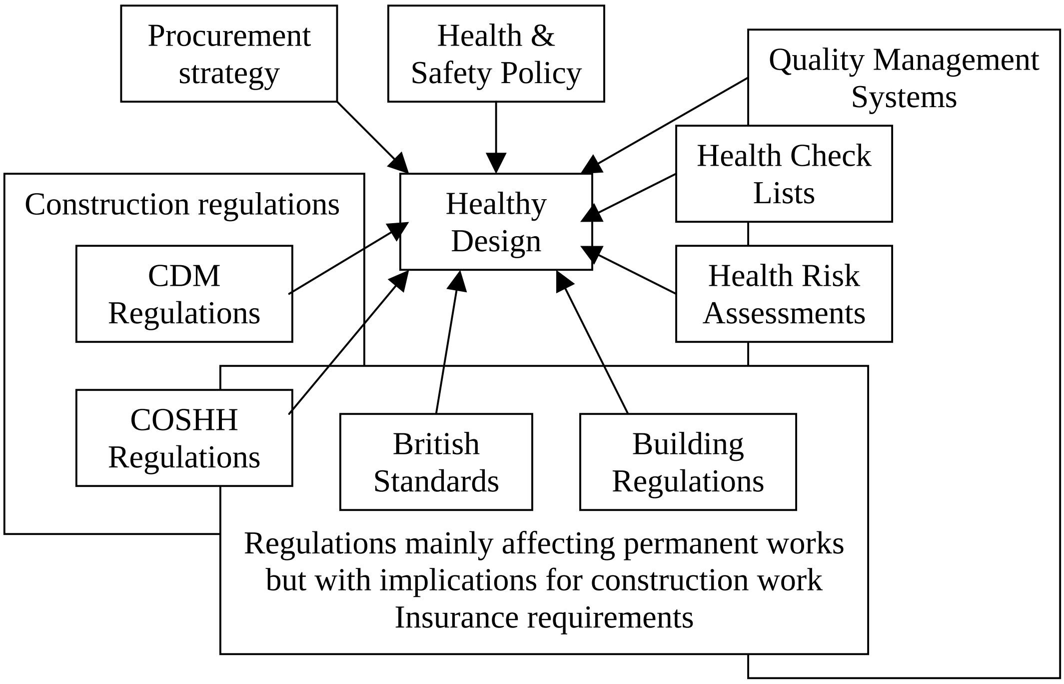

Figure 1 Influences on healthy design

The majority of health design procedures followed were driven by Risk Assessments (RA). Formal Quality Assurance (QA) procedure drivers as part of a Quality Management System (QMS) were cited by a few and these included checklists and Risk Assessments. Others relied on British Standards, the Building Regulations or COSHH (Control of Substances Hazardous to Health) regulations, all of which mainly cover the performance of the completed building. One interviewee noted that they carry out designs to the standards set by the insurers. Insurers requirements are often more stringent than those of the British Standards and the Building Regulations. If the requirements are not met and an incident occurs then a claim cannot be made, which could lead to a major financial loss on a project. It is now an increasing trend that designers look at the insurance requirements for a design rather that of the Building Regulations and British Standards.

Most of the interviewees stated that everyone in the company is responsible for healthy design. Designers tended to report to project engineers or specific CDM managers, design directors or principal architects who then report to a board of directors and ultimately to the Managing Director. Therefore it was seen as important to keep everyone ‘in the loop’. Checks were done through internal and external audits.

3.2 Legal Requirements

The majority of interviewees said that achieving more healthy designs was influenced by both legal requirements and the company health and safety policy. 3 interviewees said it was mainly legally driven and 3 interviewees said it was mostly company policy driven. No-one stated that it was totally legal requirements or totally company policy that led to improved design.

3.3 Construction (Design and Management) Regulations (CDM)

One of the questions directly addressed the regulations, asking if CDM had altered the way that they did their design. Figure 1 illustrates their answers.

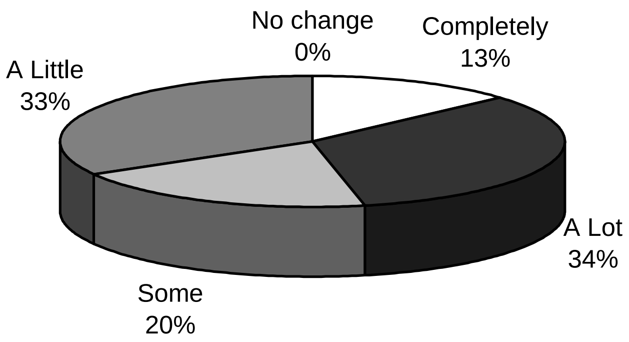

Figure 2 Has CDM altered the way you carry out your design?

CDM has improved designs related to health in projects as it has made designers more aware of health issues, specifically material used in buildings. At least two people said it had not affected the way they designed to a great extent as they worked to similar standards before CDM was introduced with CDM simply encompassing the whole process. The majority saw a marginal improvement and suggested it had not had as big an impact as it might have done. Two designers thought it had had little effect because health was difficult to include in design whereas safety was much easier to consider and often subsumed health problems. At least two interviewees claimed that CDM was not good at addressing problems for materials in terms of occupants of the building or on occupational health issues, as there was more emphasis on safety. This supports Gibb's argument (2002) that 'safety is often seen to overshadow health. Although the interviewees mentioned that CDM had made designers more aware of health issues it was unclear to what extent they were still classing health as synonymous with safety. One interviewee mentioned that a substantial amount of money had been spent on CDM and achieved nothing. However, holistically, financial risk can be significantly reduced in the event of a claim, as there would be an audit trail that designers had carried out their duty of care under CDM. Companies in the petrochemical industry stated that they felt that they had most of the CDM procedures in place already because they worked in such a hazardous industry and that they needed to have such a high health and safety standard as any accident could prove to be catastrophic.

Most interviewees felt that CDM was addressing the main areas. However, some considered that there was not enough emphasis placed on the practical issues and how to resolve them which can lead to an ineffective process – an increase in paperwork. Also identified was the disparity between domestic clients and developers, where the same project for two different clients can result in one being covered by CDM and one not. There seemed to be a lack of co-ordination between the whole construction team with the client being unaware of their legal duties under the regulations. Another problem identified was that the early notification procedure to the Health and Safety Executive (HSE – The UK Government body responsible for H&S regulation and enforcement) was an anomaly as it was not practical to notify them for every project at this early stage, especially for speculative enquiries as only a small proportion of these are taken to concept and detailed design. It was also claimed that planning supervisors (who are responsible under CDM for coordinating H&S issues mainly during design) should be appointed earlier so they are included in design process earlier, not just halfway through when it is often too late to have an effect.

The issue of high-turnover maintenance schemes is one that needs to be improved upon under CDM as there appears to be uncertainty as to whether the projects are covered by CDM. However CDM states that any project that lasts over 2 years is covered by the regulations so this type of project should be included. Furthermore there needs to be greater understanding of the legal requirements CDM has placed upon the design team. Another issue raised was that of client influence. Under CDM the client is responsible and can have a significant influence on the design – but they need to be more aware of their role. For example, the client has the responsibility to appoint a planning supervisor at the start of the project. When it was mentioned by one of the interviewees that planning supervisors are not appointed early enough it suggests that maybe the clients are not fulfilling their full responsibilities. Some felt that clients should be included in CDM training programmes and should be required to do a health and safety audit trail similar to that of designers.

3.4 Quality Management Systems

There has been an ongoing debate about the pros and cons of incorporating health and safety within a Quality Management System (QMS) as far back as the early cib w99 conferences (eg cib w99, Lisbon, Portugal, September 1996 – Proceedings edited by Alves Dias & Coble). The D^4h interviewees were divided on whether relying on an overall project Quality Management System (QMS) to identify problem areas, was more effective than using specific health-related checklists or the Health and Safety Policy. Some company's QMS incorporated checklists and health and safety policies. Others mentioned that health and safety policies do not tend to be read, just left on a shelf therefore the QMS itself was used as it could provide specific information for audits. Some identified that health and safety was not discussed as part of the QMS review and instead used checklists and RAs to identify problems. One interviewee mentioned that QMS and health and safety policies tend to merge but the QMS could not replace the health and safety policy. Some companies had a QA manager to ensure policy implementation. One interviewee stated that QMS did not fulfil the CDM obligations, because the QMS can do as much or as little as the company likes as long as it complies with the 'Standards', which could result in the QMS being very 'slack' or very 'tight'. The QMS was seen as being more project-specific with the H&S checklist being a higher standard as it was more 'hands-on'. Another interviewee mentioned that the QMS encompassed everything as it is part of a system so it can improve health and safety issues. It does need to be a live document that is constantly updated, as the design team will respect it more if it is kept up to date. Another interviewee stated the quality department deals only with procedures and is only concerned at getting designs completed.

The QMS seems still to be an area of controversy. Some integrate H&S into their QMS as a matter of course as it works well within their company structure whereas others are more sceptical of it and feel happier using other methods. It appeared to be dependent on the type of company. Many companies are comfortable using a QMS, claiming it achieves a better quality of product and also ensures that health issues are included in the design. Nevertheless, some companies argued that were unable to use QMS but that they already had systems in place that allowed them to audit health input to the design process.

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Most RAs were carried out throughout the design process, especially at pre-tender stage, so that they could be included in the tender. Most used the high, medium and low probability of risk model, if the RA identifies a significant risk, then they would look at designing-out the activity. One interviewee stated that they did not use the risk probability method as they felt it was very subjective and therefore dependent on the person who carried out the assessment. One interviewee stated that they would like more explanation from the HSE on how to carry out RAs.

RAs should be used to identify residual risks including things such as site conditions. Some only carried out RAs if the checklists identified a particular problem.

It was admitted that many RAs were carried out 'after the event' as individuals were afraid that they might get audited! Furthermore Ash (2000) stated that it was common to assess risk too late in the process to have any beneficial effects. It is imperative that RAs are used to actually identify risks and the importance of completing them properly is instilled into designers from the beginning. Changes in the attitude of the individual and, to some extent the company, need to be implemented to ensure that healthy design is automatically included, not something that is an after thought. Interviewees claimed that this will lead to improved design, ultimately making the company more competitive.

Interviewees acknowledged that the RA document needs to become a live document, constantly updated throughout all design phases from inception through to handover. It must constantly evolve and be project-specific, as it will not address specific details if only in generic form. One company started RAs on the first day of the project by setting up a risk register, which focused on site-specific issues ensuring a 'live' document was created and kept updated throughout the project.

If the designers had input into the design of the RA form, they were more likely to use it, as they would value the RA more. The RA outcome was usually then indicated on the drawings.

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The majority of the interviewees thought checklists should be used in both in concept and detailed design stage. Five interviewees thought they were best used in concept design whereas only one thought they were better in detailed design. Furthermore, they appear to be useful at concept design stage as prompts for designers due to time constraints. At the detailed design stage, designs are committed so there is a limit to what can be changed and cost implications to any changes. However, in detailed design there are more possibilities to look at maintenance issues and focus on the materials.

One suggestion was to have standard checklists with specific sections depending on the project, then include user notes to ensure that the design team are aware of the issues. The overall opinion was that it would be useful to have checklists relating to specific design briefs such as cladding or pre-stressed concrete, especially if the designer did not have much expertise in that particular area. Then they could relate it to a stage in the design. It would be useful to have a quick checklist as long as it was implemented properly within the company guidelines and was not too over complicated. One interviewee mentioned that information relating to the demolition should also be included, as there are likely to be health issues that need to be considered.

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3.7 Project Procurement

The interviewees were split over which was the best and worst procurement route for healthy design. Two interviewees stated that no one method was worse than another - the problem was the way the contracts were structured. The more favoured routes were where the contractor was appointed early enough to have design input or had some kind of partnering involvement. These methods included Partnering; the Private Finance Initiative (PFI); Alliancing; Design-Build-Finance-Operate; construction management; and management contracting. The traditional, lump-sum, design-then-build route was favoured by some as it allowed time for drawings to be completed.

Conversely, 'Design and Build' was disliked by these interviewees because of the perceived lack of scope for planning and failure to consider lifecycle issues in a drive to reduce capital cost. The designers felt they were often 'bulldozed' into using low cost options attempting to save the contractor money. Designers also considered they had a lack of control but retained the responsibility and liability for the design which was not eventually built to the original specification. The view was that drawings were often not of a good standard as they are frequently 'rushed'. In addition, incomplete inquiries or tenders tend to be fast-tracked and may not be properly thought through.

Generally, procurement routes that allowed designs to be completed and consider all aspects from conception to demolition were favoured by designers as they had most control over them. Great value was seen when the contractor and designer worked together as knowledge sharing could occur which would lead to a design that not only incorporated health and safety aspects but ultimately culminated in a superior project. Projects where contractors 'shut-out' designers after the initial design were considered the worst as the designers may still be liable for the design but have no control over it.

The majority of the interviewees considered that designers should not specify work methods as they do not have enough experience. It would be useful, however, to specify certain special consideration areas by making notes on drawings as they are usually the only item the installer on site actually sees. Designers should specify a healthy design. They should be able to justify that they have considered a healthy method of constructing their design and that they are satisfied with it. Interviewees mentioned that it should be a team effort with the designer and contractor interacting over the design and construction phase but this was seen to be dependent on company structure and procurement route.

3.8 Training to design-out health problems

Most of the interviewees had been trained at University or College prior to the introduction of the CDM regulations. Figure 3 shows that most had very little H&S training.

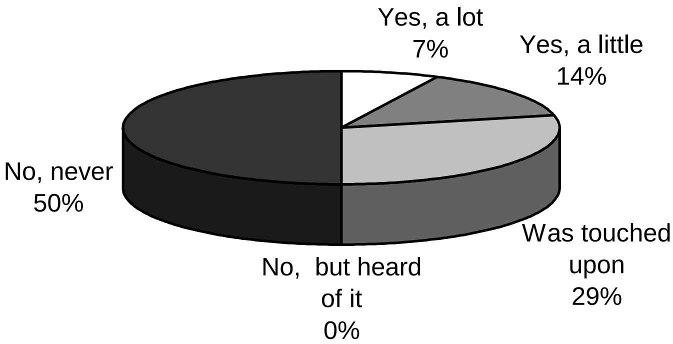

Figure 3 Were you taught about designing-out health problems whilst training to become a designer?

Today it appears that there has been only a small change in the way universities and colleges include health and safety issues. A few have integrated H&S throughout the course or even occasionally as a core module. Under CDM it is the designer's duty to keep up to date with new legislation. When asked about training on current health regulations, most interviewees had CDM training when CDM first came in but have not had any health and safety training for at least 1-2 years.

Furthermore, it appeared to be difficult to find a good CDM course as they were often too repetitive and rarely geared towards designers. Many considered that the courses merely went over the CDM regulations and they did not actually teach them anything new. They would prefer to have discussions and practical examples of how to overcome the problems through case studies examples. Many of the designers did their own research with materials, often sourced from the web or updates from HSE. Some claimed that because their company was multi-disciplinary they could use expert advice within the company when it was needed. Some had structured training courses whereas others carried out training on an ad hoc basis, particularly for new starters. One interviewee admitted that he was very sceptical about training, as often the participants tend to switch off during the course. In addition it was better to have hands-on experience and find better ways to implement training. One company had a partnering arrangement with a professional health and safety consultancy that did all their training.

Continuing Professional Development (CPD) was suggested as a way companies can keep up to date on new developments. In house seminars, industry specific courses, day or lunchtime courses were suggested as other ways of implementing training. Time role reversal was also suggested i.e. architects considering the problems engineers face and vice versa to raise inter-discipline awareness.

On-site training was seen to be one of the best methods of promoting training yet many designers spend minimal time on site and have no idea of the problems that can occur. A site when dry could be a completely different scenario when it is muddy and wet. It is issues like this that designers need to be aware of and consider how different environmental conditions may alter the process.

4 Conclusions

These preliminary findings indicate that healthy design is influenced by a number of aspects. The construction regulations (eg CDM & COSHH) have a direct bearing, but so, to a certain extent, do regulations covering the end-product building or facility. Quality Management Systems, incorporating risk assessments and check lists are considered effective, although some interviewees would prefer to use these tools outside of a formal QMS. The overall health and safety policy was also considered to be a significant influencer, although these were often too generic to be of much use. Procurement routes were considered to be important, with those that facilitated collaboration between designer and constructor being favoured. Traditional 'design-then-build' was considered to be preferable to contractor-led 'design-and-build' as it was seen that the contractor often ignored the original design principals in amending the design but still required the original designer to retain H&S responsibility. Training to incorporate health considerations for construction workers was sparse and poorly organised. This remains as an important barrier to healthier design.

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D^4h – Influences on Designing for Health

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Abstract

D^4h is a two-year UK Government-funded research project developing a strategy for best practice in designing construction projects to account for the occupational health of construction workers. For many years, health has been the 'poor relative' of safety in 'health and safety' considerations. This is an important issue where little in-depth work exists although it is rapidly becoming a key issue for many European countries. The European Temporary and Mobile Construction Sites Directive, leading to CDM in the UK, has stimulated a change in design culture in many states with designers being expected to explicitly acknowledge health and safety in their designs and seek to reduce or remove risk to construction workers. However, all the concentration so far has been on safety, to the exclusion of occupational health, except for issues surrounding hazardous substances. This paper presents the preliminary findings from the first phase of the D^4h project, namely semi-structured interviews of experienced design practitioners and managers regarding design phase provision for occupational health of construction workers. The intention of this paper will be to raise the principal issues regarding design influences and provide a platform for further debate.

Keywords

European TMCS Directive, CDM, Healthy Design, Risk Assessment

1 Introduction

The Construction (Design and Management) Regulations (CDM) were introduced in the UK in March 1995, derived from the European Directive on Temporary and Mobile Construction Sites (92/57/EEC). This directive has been dealt with at length in as can be seen in the CIB conference proceedings, Safety Co-ordination and Quality in Construction (1999) which contains reports from throughout Europe on implementation of the Directive. Smallwood et al (2000) stress that 'design precedes construction and consequently designers have the greatest potential in terms of contributing to the minimising and/or eliminating of the risk posed by hazardous chemical substances'. Duff & Suraji (2000) also explain that the design role is 'not only associated with providing better design outputs but also minimising negative effects of the design process and maximising the value of their design skills and project knowledge'.

'Health and Safety is often used by experts and non-experts alike to represent only safety. Most health and safety managers, supervisors or inspectors have little more than a very rudimentary knowledge of occupational health issues' (Gibb, 2002). The authors argue that this is also true of designers. Every year many thousands of construction workers suffer from work-related ill health. In 1995, the UK's self-reported work-related illness survey found an estimated 134,000 construction-related workers report a health problem caused by their work, resulting in an estimated 1.2 million days lost in a workforce of 1.5 million (Gibb 2002). In particular there were 96,000 musculoskeletal disorder cases; 15,000 respiratory disease cases; 6,000 cases of skin disease and 5,000 noise induced hearing loss cases. Hand arm vibration syndrome (HAVS) has also been identified as a health hazard as shown by recent research (Gibb 2002).

The European Construction Institute (ECI) produced a guide to managing health in construction (ECI 1999). It includes strategies to manage health throughout the construction process and gives information on regulations for health issues in European countries. This manual is mainly targeted at construction managers, so the D^4h project is applying some of this previous work and develop practical guides for designers. The overall strategy of D^4h is to identify and build on current 'best practice' where it exists for healthy design, particularly issues relating to the construction process. Currently, little exists which can be used as a benchmark and there is little specific guidance for healthy design.

2 Methodology

This paper presents the preliminary findings from the first phase of D^4h, namely interviews of experienced design practitioners and managers regarding design phase provision for occupational health of construction workers. A 19 question semi-structured interview was developed and piloted. In addition to some closed questions to gather comparative data, many of the questions were open-ended to allow discussion to evolve and it is these questions that form the basis of this paper. Individuals were asked to give their own opinion, not just that of company policy. Interviewees were designers selected from individuals linked to the project steering group, the ECI and other design experts employed in the construction sector. 14 individuals were interviewed, from various construction sectors including petrochemical, architectural, and design contractors. The interviewees are described in Table 1.

Table 1. Background data on interviewees

Interviewee Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Specialist Area														Data unavailable
Architect	X				X			X	X					
Structural Engineer		X												
H&S/CDM Manager			X				X							
Civil Group Manager				X										
Design/Technical Manager						X				X	X		X	
Head of Support												X		
Years Experience														Data unavailable
0-10		X												
11-15			X					X					X	
16 - 20				X						X	X			
21-25						X	X							
26-30	X								X			X		
30+					X									
Gender														
Male	X			X	X	X	X	X	X	X	X	X	X	X
Female		X	X											
Project Types														Data unavailable
Petrochemical/Power				X										
Residential			X				X	X	X		X			
Civil	X		X							X		X	X	
Commercial	X	X	X			X	X	X	X					
Retail	X	X	X			X	X	X						
Educational	X		X				X	X						
Recreational	X		X			X	X	X	X					
Light Industrial	X	X	X		X	X	X	X	X					
Pharmaceutical				X	X							X		
Airports											X			

3 Results and Discussion

3.1 Healthy Design Procedures

The basis of the procedures used for designing for healthy construction varied significantly across the interviewee’s organisations. It was difficult in most of the interviews to separate out occupational health issues from the overall health and safety issues. Several of the companies had extensive documents outlining guidance for designers that incorporated CDM requirements. Figure 1 illustrates the influences on design to take account of the occupational health of construction workers.

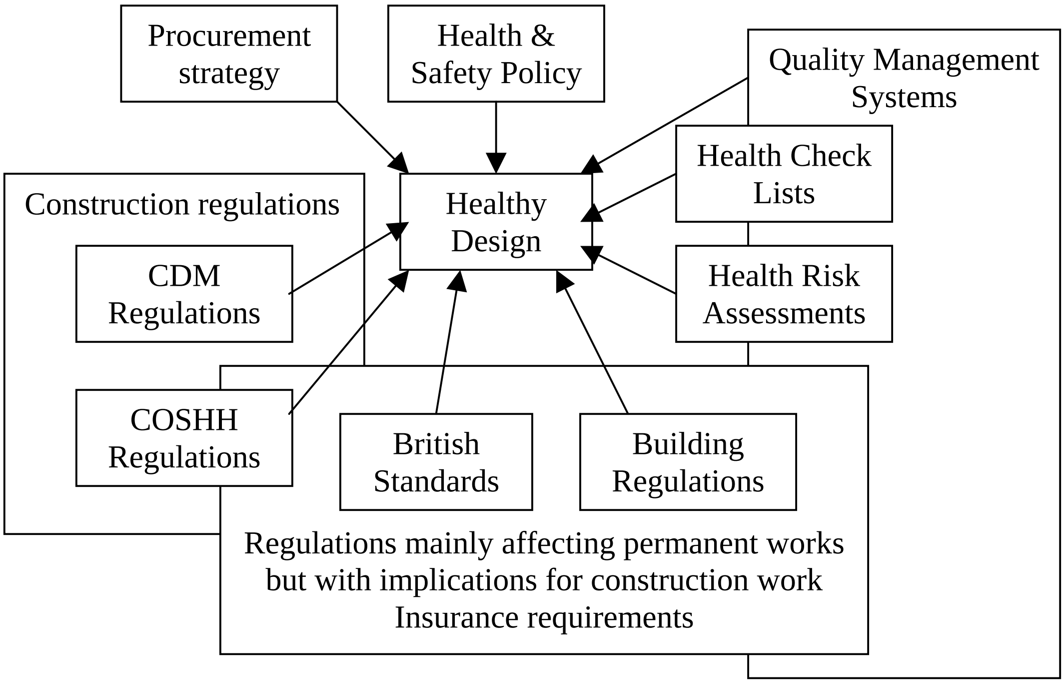

Figure 1 Influences on healthy design

The majority of health design procedures followed were driven by Risk Assessments (RA). Formal Quality Assurance (QA) procedure drivers as part of a Quality Management System (QMS) were cited by a few and these included checklists and Risk Assessments. Others relied on British Standards, the Building Regulations or COSHH (Control of Substances Hazardous to Health) regulations, all of which mainly cover the performance of the completed building. One interviewee noted that they carry out designs to the standards set by the insurers. Insurers requirements are often more stringent than those of the British Standards and the Building Regulations. If the requirements are not met and an incident occurs then a claim cannot be made, which could lead to a major financial loss on a project. It is now an increasing trend that designers look at the insurance requirements for a design rather that of the Building Regulations and British Standards.

Most of the interviewees stated that everyone in the company is responsible for healthy design. Designers tended to report to project engineers or specific CDM managers, design directors or principal architects who then report to a board of directors and ultimately to the Managing Director. Therefore it was seen as important to keep everyone ‘in the loop’. Checks were done through internal and external audits.

3.2 Legal Requirements

The majority of interviewees said that achieving more healthy designs was influenced by both legal requirements and the company health and safety policy. 3 interviewees said it was mainly legally driven and 3 interviewees said it was mostly company policy driven. No-one stated that it was totally legal requirements or totally company policy that led to improved design.

3.3 Construction (Design and Management) Regulations (CDM)

One of the questions directly addressed the regulations, asking if CDM had altered the way that they did their design. Figure 1 illustrates their answers.

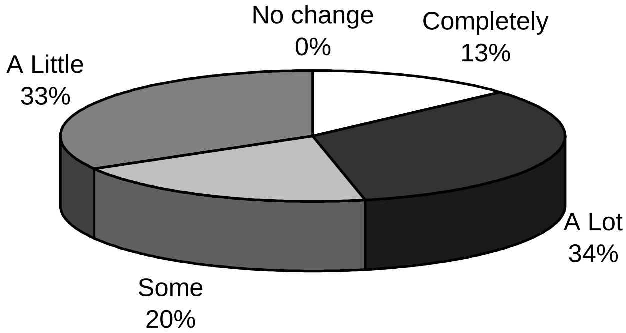

Figure 2 Has CDM altered the way you carry out your design?

CDM has improved designs related to health in projects as it has made designers more aware of health issues, specifically material used in buildings. At least two people said it had not affected the way they designed to a great extent as they worked to similar standards before CDM was introduced with CDM simply encompassing the whole process. The majority saw a marginal improvement and suggested it had not had as big an impact as it might have done. Two designers thought it had had little effect because health was difficult to include in design whereas safety was much easier to consider and often subsumed health problems. At least two interviewees claimed that CDM was not good at addressing problems for materials in terms of occupants of the building or on occupational health issues, as there was more emphasis on safety. This supports Gibb's argument (2002) that 'safety is often seen to overshadow health. Although the interviewees mentioned that CDM had made designers more aware of health issues it was unclear to what extent they were still classing health as synonymous with safety. One interviewee mentioned that a substantial amount of money had been spent on CDM and achieved nothing. However, holistically, financial risk can be significantly reduced in the event of a claim, as there would be an audit trail that designers had carried out their duty of care under CDM. Companies in the petrochemical industry stated that they felt that they had most of the CDM procedures in place already because they worked in such a hazardous industry and that they needed to have such a high health and safety standard as any accident could prove to be catastrophic.

Most interviewees felt that CDM was addressing the main areas. However, some considered that there was not enough emphasis placed on the practical issues and how to resolve them which can lead to an ineffective process – an increase in paperwork. Also identified was the disparity between domestic clients and developers, where the same project for two different clients can result in one being covered by CDM and one not. There seemed to be a lack of co-ordination between the whole construction team with the client being unaware of their legal duties under the regulations. Another problem identified was that the early notification procedure to the Health and Safety Executive (HSE – The UK Government body responsible for H&S regulation and enforcement) was an anomaly as it was not practical to notify them for every project at this early stage, especially for speculative enquiries as only a small proportion of these are taken to concept and detailed design. It was also claimed that planning supervisors (who are responsible under CDM for coordinating H&S issues mainly during design) should be appointed earlier so they are included in design process earlier, not just halfway through when it is often too late to have an effect.

The issue of high-turnover maintenance schemes is one that needs to be improved upon under CDM as there appears to be uncertainty as to whether the projects are covered by CDM. However CDM states that any project that lasts over 2 years is covered by the regulations so this type of project should be included. Furthermore there needs to be greater understanding of the legal requirements CDM has placed upon the design team. Another issue raised was that of client influence. Under CDM the client is responsible and can have a significant influence on the design – but they need to be more aware of their role. For example, the client has the responsibility to appoint a planning supervisor at the start of the project. When it was mentioned by one of the interviewees that planning supervisors are not appointed early enough it suggests that maybe the clients are not fulfilling their full responsibilities. Some felt that clients should be included in CDM training programmes and should be required to do a health and safety audit trail similar to that of designers.

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3.7 Project Procurement

The interviewees were split over which was the best and worst procurement route for healthy design. Two interviewees stated that no one method was worse than another - the problem was the way the contracts were structured. The more favoured routes were where the contractor was appointed early enough to have design input or had some kind of partnering involvement. These methods included Partnering; the Private Finance Initiative (PFI); Alliancing; Design-Build-Finance-Operate; construction management; and management contracting. The traditional, lump-sum, design-then-build route was favoured by some as it allowed time for drawings to be completed.

Conversely, 'Design and Build' was disliked by these interviewees because of the perceived lack of scope for planning and failure to consider lifecycle issues in a drive to reduce capital cost. The designers felt they were often 'bulldozed' into using low cost options attempting to save the contractor money. Designers also considered they had a lack of control but retained the responsibility and liability for the design which was not eventually built to the original specification. The view was that drawings were often not of a good standard as they are frequently 'rushed'. In addition, incomplete inquiries or tenders tend to be fast-tracked and may not be properly thought through.

Generally, procurement routes that allowed designs to be completed and consider all aspects from conception to demolition were favoured by designers as they had most control over them. Great value was seen when the contractor and designer worked together as knowledge sharing could occur which would lead to a design that not only incorporated health and safety aspects but ultimately culminated in a superior project. Projects where contractors 'shut-out' designers after the initial design were considered the worst as the designers may still be liable for the design but have no control over it.

The majority of the interviewees considered that designers should not specify work methods as they do not have enough experience. It would be useful, however, to specify certain special consideration areas by making notes on drawings as they are usually the only item the installer on site actually sees. Designers should specify a healthy design. They should be able to justify that they have considered a healthy method of constructing their design and that they are satisfied with it. Interviewees mentioned that it should be a team effort with the designer and contractor interacting over the design and construction phase but this was seen to be dependent on company structure and procurement route.

3.8 Training to design-out health problems

Most of the interviewees had been trained at University or College prior to the introduction of the CDM regulations. Figure 3 shows that most had very little H&S training.

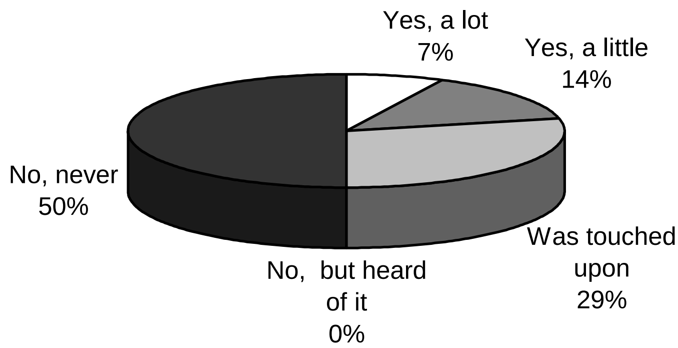

Figure 3 Were you taught about designing-out health problems whilst training to become a designer?

Today it appears that there has been only a small change in the way universities and colleges include health and safety issues. A few have integrated H&S throughout the course or even occasionally as a core module. Under CDM it is the designer's duty to keep up to date with new legislation. When asked about training on current health regulations, most interviewees had CDM training when CDM first came in but have not had any health and safety training for at least 1-2 years.

Furthermore, it appeared to be difficult to find a good CDM course as they were often too repetitive and rarely geared towards designers. Many considered that the courses merely went over the CDM regulations and they did not actually teach them anything new. They would prefer to have discussions and practical examples of how to overcome the problems through case studies examples. Many of the designers did their own research with materials, often sourced from the web or updates from HSE. Some claimed that because their company was multi-disciplinary they could use expert advice within the company when it was needed. Some had structured training courses whereas others carried out training on an ad hoc basis, particularly for new starters. One interviewee admitted that he was very sceptical about training, as often the participants tend to switch off during the course. In addition it was better to have hands-on experience and find better ways to implement training. One company had a partnering arrangement with a professional health and safety consultancy that did all their training.

Continuing Professional Development (CPD) was suggested as a way companies can keep up to date on new developments. In house seminars, industry specific courses, day or lunchtime courses were suggested as other ways of implementing training. Time role reversal was also suggested i.e. architects considering the problems engineers face and vice versa to raise inter-discipline awareness.

On-site training was seen to be one of the best methods of promoting training yet many designers spend minimal time on site and have no idea of the problems that can occur. A site when dry could be a completely different scenario when it is muddy and wet. It is issues like this that designers need to be aware of and consider how different environmental conditions may alter the process.

4 Conclusions

These preliminary findings indicate that healthy design is influenced by a number of aspects. The construction regulations (eg CDM & COSHH) have a direct bearing, but so, to a certain extent, do regulations covering the end-product building or facility. Quality Management Systems, incorporating risk assessments and check lists are considered effective, although some interviewees would prefer to use these tools outside of a formal QMS. The overall health and safety policy was also considered to be a significant influencer, although these were often too generic to be of much use. Procurement routes were considered to be important, with those that facilitated collaboration between designer and constructor being favoured. Traditional 'design-then-build' was considered to be preferable to contractor-led 'design-and-build' as it was seen that the contractor often ignored the original design principals in amending the design but still required the original designer to retain H&S responsibility. Training to incorporate health considerations for construction workers was sparse and poorly organised. This remains as an important barrier to healthier design.

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Evaluation of work conditions in the Brazilian civil construction industry

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Abstract

The construction industry is passing through a transformation process that reaches all phases within the productive process. However, it was verified during the execution phase that a high rate of work accidents and occupational diseases were caused, among other reasons, by a lack of appropriate planning, ignorance and non-regiment of the legal conditions of management, and safety and health in work. It's increasing the managerial organizations that are observing the need to accomplish investments in the area of health and safety. The Brazilian government reedited and it maintains an updated regiment that establishes guidelines to administrative order, planning and organization, and aims to the improvement of control measures and preventive systems of safety in these processes, in the conditions of work environment and in the industry of construction. In this point-of-view, this article tries to verify the effective implantation of this regiment in civil constructions and to analyze the conditions in work development in the industry of Brazilian civil construction. It intends to demonstrate that, by investing in the safety and worker's health, the investor will be developing the quality of his collaborators' life above all.

Keywords

Occupational health and safety; civil construction; site; legislation.

1 Introduction

In Brazil, the industry of building sites absorbs a great number of workers and it has a prominence in the national economy, representing 9% in the gross domestic product in 1998, in agreement with the Construction Industry Commission. In spite of that, it is difficult to modernize, mainly in relation to the management of the present physical resources in construction sites.

The importance and the characteristics of that section demanded the elaboration of a specific regulation from the governmental organs for that activity branch, for its peculiarities and for the high risk that contains. In 1995, a tripartite commission reviewed the regiment of health and safety with workers' representatives, entrepreneurs and the government. As result, the Regiment Norm 18 (NR-18) was created, and produced several progresses in the sector (Brazil, 2001). An immediate consequence of its implantation was observed to be a decrease in the high indexes work accidents.

PCMAT - Conditions and Environment of Work in the Industry of the Construction Program -, created by NR-18, establishes goals and priority actions in the prevention to the environmental risks in the industry of building sites, which must be in companies where there are 20 workers or more. In spite of the reduction on the index of accidents, it is verified that most of the programs presented by the companies of industry construction still presents implantation difficulties and it doesn't reach the expected results (Brazil, 2001).

In the other hand, was observed that most of the accidents in the building sites are motivated by administrative fails (management) and not by operational origin. It contributes to a lack of workers' literacy, that doesn’t get much time to read or to understand the warnings to maintain the safety. Many accidents could be avoided if the companies also developing programs of safety and health in work give special attention to education and its workers' training.

It was verified that the great inductor of the existent alterations was the government, which started to pay attention to work execution better and to demand in public auction processes the presentation of minima indicators of health and safety at work.

As a manner of reducing the risk of accidents in the building site, the Safety and Health of Labor Division (DSST) of the Regional Police station of Work in São Paulo State (DRT/SP) it is privileging the actions and the suitable programs for the syndicate demand and for the several technical and academic entities related to safety's area (DRT/SP, 2001). In this sense, the most important actions are those directly involved with classes of building sites, not leaving aside other areas. For example: services (data processing and bank branch) and trade (supermarkets).

The Brazilian Program of Quality and Productivity of the Habitat - PBQP-H - also has, as one of its principal goals, the reduction of the number of accidents at work in building sites, inserting fundamental concepts of division of the responsibilities among all the segments that participate in the construction: builders, suppliers of materials and equipment, subcontractors, workers etc. (Brazil, 2002).

However, it is observed that some difficulties are generated from the moment that, the entrepreneurs and those that are responsible for the implantation of the program don't commit with its maintenance. In that way, it is verified the necessity study and electric outlet preventive measures in the building site, so that the execution and safety walk closest.

2 The management of the work environment

It is observed that the construction site is a dynamic and very flexible structure, assuming during the development of the building different characteristics in the workers' function, companies, materials and present equipment in it. Several attitudes should be taken to facilitate the development of work, such as the implantation of quality politics, the development of suppliers and subcontractors, the use of computational tools, etc. The programming should be united with all the intervening agents and constantly reviewed in order to avoid faults in the process.

With all this, difficulty is observed in guaranteeing the comfort and the workers' safety that execute the work. That is exactly one of the reasons of the high index of accidents.

One of the outstanding characteristics of the industry of building site is its temporary character and the specifically of each product. The qualification of the labor is, however, precarious or even inexistent.

According to Construction Civil Industry Committee writing on the Brazilian Program of Quality and Productivity of the Habitat (Brazil, 2002), the area of human resources in companies of the section is characterized by the inadequacy of training programs, little investment in professional formation, decline on degree of ability and on workers' qualification along the last years, high rotation rates in work sources and lack of formation programs in labor level. We can still increase the existence of uncomfortable work conditions and productive processes with high risks.

As Cordeiro; Machado (2002), the implantation of a quality and productivity program many times it finds resistance by the workers in an initial period. On the other hand, the implementation of certain procedures and technologies demand a reorganization of the competences that is going from the workers to the discharge management of the building companies. Therefore, before implanting changes in the work environment, it is important that there is an understanding of the involved workers, independent of the hierarchical level in that they are. Managers and workers should be conscious of the risks and the needs that implantation could changes.

In that context, the needs should be known and which factors are significant so that there is a compromising degree on the part of workers, grouping aspects of their social context and other relative to life quality in work environment.

The lack of a cash management in the work environment can be the cause of accentuated number of serious and fatal accidents in the construction industry. Like this, as Moreira Lima Jr. (2001), the Management Risks is translated fundamentally in the reduction of diseases and accidents in work and accidents related to damage of property.

The improvements are clearly observed in work environments after the change of NR-18, in agreement with Bocchile (2002). The technical and organizational pattern is also modifying, quickly due to the demands of smaller costs and larger quality. However, the constructions sub-sectors are still characterized by believing that the implantation of the legal demands in prevention constitutes an additional cost to the work.

3 The management of the health and safety of the work

Safety and health’s norms should represent the practice in prevention and to correctly define the responsibilities of all involved. At the same time, the legislation should be dynamic to accompany the evolution and technological innovations in the building site sector.

It is also verified that many entrepreneurs of building sites don't possess the understanding of the concept providing a life quality in the work environment and, for consequence; they don't possess politics of human resources.

Another analysis concerns workers' understanding. Cordeiro; Oliveira (1999) mentions that although one pointed factors for the entrepreneurs as critical for the full implementation of the norm NR-18 was the lack in workers' conscience in exact relationship to the subject in health and safety. That shows the need of intensive training and education programs to solve the problem.

In spite of the integral execution of NR-18 not to be enough for a significant reduction in the accidents rates, it should be faced the current norm as a basic requirement to be obeyed. That statement is based in the international bibliography, because in developed countries where the technological landing construction is thankfully superior to the Brazilian, the managerial measures have been prioritized to reduce the high accident indexes in construction (Herper; Kohen, 1998).

Hinze (1997) points out that, in a general way, accidents can be avoided or minimized through managerial measures associated with the implantation of safety's physical facilities. In addition, the development of a safety program substitutes the simplistic practice just to the implantation of safe facilities.

Education for the workers' safety can also be an effective tool to minimize work accidents. As Wilson Jr.; Koehn (2000), the more frequent the training occurs the more efficient safety measures will be practiced in everyday work. The training will have a large useful degree when supplied with aid of didactic material previously elaborated and still foreseen specific training driven to the work engineers, masters and person in charge.

Picchi (1993) observes that the training in construction sector is chronically deficient and it can harm any effort of improvement in quality. Personnel's qualification is an important mechanism, so much for the warranty in quality, as a recognition mechanism and career formalizes. Picchi (1993) suggests that the training should embrace three aspects: education (literacy, orientations with relationship to the documentation and rights, health campaigns etc.); training for the production (preparation for acting specific position); and training for the quality (importance, politics of the company, activity control of the quality that affect their activities etc.).

The system of quality should possess a fort-understanding and motivation component to the quality with well-known benefits for the external customer, company and your employees. Starting from the quality’s work plan, analysis of nonconformities and acting processes, the managers should annually identify training needs. Based on the work plan, an annual training plan subject to alterations is elaborated according to needs. Nevertheless, according to Picchi (1993), the effectiveness of training can be evaluated through the observation of a record verification service, which registers the inspection situation and re-inspection, indicating the work level in the respective services for which the employees were workout.

According to Bocchile (2002), the worker should receive six minimum hours of admittance training. He should pass also for periodic recycling to use the Personal Protection Equipment (PPE) and to have specific courses for operation of equipment, such as tow-truck, mountain to circulate or pistol, and to receive notions of personal hygiene. Such procedures seek to give the workers a larger satisfaction and motivation, which are important factors to success and quality inside the company.

4 Methodology

This research approaches results referring to the characterization in work environmental conditions in 10 visited construction sites in the São Carlos city, Brazil, in the year 2002. All the visited construction sites were characterized by being located in the urban perimeter of the city. The builders possess local headquarters and they can be characterized as mini and small companies.

The necessary information for characterization of the construction sites were obtained through interviews with engineers and master’s works, through the completion of a questionnaire and the registration of the conditions with a video camera.

The research method was created to understand the following stages: study and reconstruction of the questionnaire or verification list, field research, interviews and analysis of the results.

The composition of the demands and the configuration of the list were based on the procedures adopted by the Building Innovation Research Unit (NORIE, 2002). It also followed the criteria adopted by Saurin; Formoso (1997), where the answers marked with the option “yes” represent the positive aspects (greeting of the norm) and the answers marked with “no” represent the negative aspects. On the other hand, the answers marked “it is not applied” (INA) indicated demands that were not necessary in the stonemason, be due to typology of work or the execution phase in the visit's day.

5 Data analysis

Along the accomplished visits could be identified the demands of NR-18 that the companies accomplished less and which those that the companies are having larger implantation difficulties, investigating the causes of such situations.

It was also possible to document, close to the building companies of the city, good examples of the relative safety practices in work. The Tables 01, 02, 03 and 04 present a list with elaborated verification, followed by figures showing the demands of NR-18 that are accomplished integrally by the visited companies.

To guarantee life quality, hygiene conditions and the employee's integration in the society, with reflexes in the productivity of the company, new NR-18 determines that the work stonemasons contain existence areas that reflect your dignity.

The place for meals should possess floor made with washable material and tables with flat and washable lids. The refectory cannot be placed at underground or base construction sites. The Figures 01 and 02 identify a good example, where besides the existence of an appropriate table, the place has good conditions of safety and hygiene to heating meals.

Table 01 - Verification List for the refectory (adapted of NORIE, 2002)

18.4.2.11. PLACE FOR MEALS The construction site has a place for meals () yes () no			
If the answer no goes, pass to the item 18.4.2.12.	Yes	No	INA
a) has walls that allow isolation during the meals			
b) has concrete floors, cemented, or other washable material			
c) has covering that provides protection from bad weather			
d) has ventilation, natural and/or artificial illumination			
e) there is a lavatory installed in its proximities or in its interior			
f) there are enough seats to assist users			
g) has deposit with cover for debris			
h) it's placed at underground or basements of constructions			
i) has Entitled of at least 2,80 m			
18.4.2.11.3. There is exclusive place endowed with safe equipments for the heating of the meals			
Notes:			

Figure 01: Refectory maintained in perfect state of cleaning, with enough seats to assist the 25 active workers. The illumination and ventilation are appropriate, providing more comfort.

Figure 02: Device for safe heating of workers' meals. To the bottom, lavatories are also observed in appropriate number and in hygiene conditions.

Several studies identify one of the largest risks in building sites are falling materials or workers. Like this, the collective protection measures against height falls (as trays, guard-body and other) are obligatory and priority. In a place where that is not possible, the worker should use the type parachutist's safety belt. It also makes part of NR-18 the use of collective protection measures against falls of materials and tools on the worker. Tables 02 and 03 show the items analyzed that obstructs devices or reduce these types of accidents. Figures 03, 04 and 05 show examples of the application of those devices on safety.

Metallic beams conveniently fastened to the structure of the building should sustain when the service happens in suspended scaffolds. They should have guard-bodies and should be covered with screens that impede falling materials. Figure 06 portrays a situation of suspended scaffolds.

Table 02 - Verification List for protection measures against falls of heights (adapted of NORIE, 2002)

18.13. MEASURES OF PROTECTION AGAINST FALLS OF HEIGHT	Yes	No	INA
18.13.1. Collective protections are installed where risks of falling workers or materials exist.			
OPENINGS IN THE FLOOR () it exists () it doesn't exist			
18.13.2. All the openings in the floor have resistant temporary closing			
WELL OF THE ELEVATOR () it exists () it doesn't exist			
18.13.3. There is a temporary closing, with guard-body and baseboard, of at least 1,20 m of height, constituted of fixed resistant material to the structure.			
Notes:			

Table 03 - Verification List for platform of protection (adapted of NORIE, 2002)

18.13. PLATFORM OF PROTECTION (tray lifeguard) () it exists () it doesn't exist	Yes	No	INA
18.13.6. The main platform of protection is in the first flagstone that is at least a foot-right above the level of the land If it is in another it indicates:			
18.13.6.1. The main platform has width of 2,50 m (two meters and fifty centimeters) + 0,80m complement (eighty centimeters) at 45o o'clock			
18.13.7. Secondary platforms of protection exist to each 3 flagstones, starting from the main platform			
18.13.7.1.A secondary platform has width of 1,40 m (a meter and forty centimeters) + I complement of 0,80 m (eighty centimeters) at 45o o'clock respectively			
18.13.9. The construction perimeter of the building is closed with screen, starting from the main protection platform			
18.13.11. The protection platforms are built in a resistant way and maintained without overload			
Notes:			

	
Figure 03: Protection for screen installed in the last flagstone where the risk of workers' fall and projection of materials exists.	**Figure 04:** Temporary closing of the opening and steps of the stairway, of 1,20 m of height, constituted of fixed resistant material to the structure.

	
Figure 05: Secondary platforms in agreement with the measures specified in the norm. Besides those, the main platform exists in the level of the first flagstone.	**Figure 06:** Detail of suspended scaffold. It presents the measures also specified in Norm.

Table 04 - Verification List for PPE's (adapted of NORIE, 2002)

18.23. PPE's (PERSONAL PROTECTION EQUIPMENTS)	Yes	No	INA
18.23.1. The company supplies to the workers, gratuitously, appropriate PPE accordingly to the risk and in perfect conservation state			
18.23.3. The safety belt type parachutist is used by the worker whenever this executes activities more than 2,00m] (two meters) of height of the floor			
18.23.3.1. The safety belt is endowed with device restraint-falls and it is linked to a cable of independent safety to the scaffold structure.			

Associated with those protection measures, the employer should supply his workers with work vestments and replace them whenever needed. The basic clothes can be overalls or pants and a shirt. The supply of the equipment of individual protection is obligatory and defined for complementary Norms. Each PPE should be adapted to the existent and all labor risk it should be trained for your correct use. Observe in the Figures 07 and 08, examples of the use of this equipment.

	
Figure 07: Worker accomplishing service in the last flagstone of the building, prisoner to the safety belt type parachutist, obligatory for accomplished activities the more than 2 meters of the floor.	**Figure 08:** Details of worker accomplishing service in scaffold to facade and using safety belt. However, the placement of the boards for formation of work floor is precarious and insecure.

6 Final considerations

This analysis confirms the need of a cash management of work environment to improve the organization and the quality of life in construction sites.

The application of the verification list based on the check list proposed by NORIE demonstrates that all demands are viable and can be assisted, although there are demands more accomplished then others. The causes for the non execution, according to Saurin; Formoso (1997), can be attributed to the following factors: the ambiguous character of some demands, the secondary paper usually destined to the safety of work in the management of the companies, Norm's ignorance and, in some cases, technical difficulties and high costs of equipment.

An importance notice from the realized study is about the safety standard lack inside the visited building sites. This worry, most of time, is more related to the individual work of the engineer and the master builder, than the company. As an example, while one building site is worried with the peripheral protection, in others the worry is about the existence areas. The result is a low performance of health and safety of the work in the civil construction, as can be seen through the terrible conditions of work. In all visited building sites, the engineer or the master builder assured that the company use the PCMAT, but the majority (six companies) have only the document and don’t make use of it.

The attendance of all these demands will not eliminate fatalities but certainly has the potential for reducing them considerably. It is verified that in the studied area the conformity index with NR-18 grew considerably in agreement with the frequency, inclusion and educational performance on part of supervising of DRT. Another obtained die was that the contact among unions of companies and workers with public supervisors organs increased also due to safety's subject.

The results of this study indicate that the actions and identified practices can improve the conditions of the worker's life, propitiating larger effectiveness to the productive process and preservation of work relationships in the industry of building sites.

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Programmes and competitions: The role of inspections and audits in health and safety (H&S)

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Abstract

Incidents occur downstream of culture, management system and exposure. Following a programme and participating in industry competitions constitute aspects of management system and reflect management commitment. Programmes outline the aspects to be addressed; enable both management and workers to manage by objectives (MBO), and enable measurement and evaluation of health and safety performance. Competitions serve as a motivator, complement MBO, and effectively raise the level of awareness.

Inspections are a key element of a programme as they are the key to eliminate hazards, and auditing is essential to determine the effectiveness of health and safety management systems. Consequently, inspections and auditing play a major role in reducing and/or eliminating exposure. Exposure includes: behaviour; conditions; plant and equipment, and facilities and will reflect either the success or failure of management system.

This paper reviews the health and safety performance of primarily general contractor members of the East Cape MBA. The performance of both 'competition' and 'non-competition' entries are reviewed and compared relative to their overall score and scores obtained for the three main elements: administration; general housekeeping and general safety. On average, the 'competition' entries obtained a higher overall score and score for all elements, than the 'non-competition' entries.

The biggest absolute percentage difference between categories was for the element administration (31,9%) followed by housekeeping (15%), and general safety (10,6%), the overall absolute percentage difference being 19,2%. The aforementioned substantiate the role of competitions, management commitment and the need to follow a structured programme.

Keywords

Keywords: inspections, audits, programmes, competitions

1 Literature Survey

1.1 Upstream versus downstream

Figure 1 presents the upstream → downstream sequence postulated by Krause (1993). Culture, at the upstream end, influences management system, which influences exposure, which may or may not result in incidents at the end point of the sequence.

An H&S programme constitutes part of management system. H&S competitions are similar to H&S programmes in that they require the following of an H&S programme. H&S competitions are also an integral part of any improvement model.

H&S inspections enable the assessment of behaviour, conditions, plant and equipment, and facilities at the time of the inspections. Consequently, H&S inspections and auditing are both critical aspects of an H&S programme and are essential to reduce and, or eliminate exposure.

Figure 1 Incidents are downstream (Adapted from Krause, 1993).

Culture →	**Management System →**	**Exposure →**	**End Point**
Purpose	Education & training	Behaviour	Incidents
Mission	Practices	Conditions	
Values	Programme	Plant & equipment	
Vision	Site layout	Facilities	
Goals	Behaviour consequences		
Assumptions	Accountability		
	Priorities		
	Attitude		
	Measurement systems		
	Improvement model		
	Resources		

1.2 Role of H&S programmes

Moran (La Bar, 1992) maintains that for H&S effort to be successful, the implementation of a written programme is required. Bentil (1992) maintains that the development and implementation of formal H&S programme will result in improved H&S. Although a written programme is itself not enough, according to Dunn and Lehrer (1987) it is the first step a contractor can take to demonstrate reasonable efforts to provide for H&S on a project.

The Associated General Contractors of America (AGC) (1990) maintains H&S programmes are most effective when they are designed to meet the specific and individual needs of each contractor. H&S programmes outline the aspects to be addressed and enable both management and workers to manage by objectives. They also maintain it may even be useful to develop a specific H&S programme for each project.

1.3 Role of H&S competitions

Literature indicates that raising awareness, and enhancing of motivation predominate in terms of the role of H&S competitions. According to Burroughs, a large GC H&S

Coordinator, H&S competitions are necessary to motivate people to get involved in H&S and provide a form of measurement by which standards can be compared (Smallwood, 1995a).

Smallwood (1995b) maintains H&S competitions serve as a motivator, complement management by objectives, and also effectively raise the level of awareness.

Mokungwe, a Construction Union Representative (Smallwood, 1995c) says competitions play a role as they promote awareness and help save lives.

1.4 Benefits of H&S programmes

A study conducted among South African general contractors (GCs) investigated, inter alia, the relationship between management commitment criteria and cited improvement in H&S performance. Although a 'Chi-square' correlation test did not determine there to be a statistically significant relationship, H&S programmes appear to have an influence on cited H&S performance (Smallwood, 1995b).

1.5 Benefits of H&S competitions

Burroughs (Smallwood, 1995a) maintains H&S competitions engender H&S attitudes and behaviour and in the short, medium and long term, result in H&S improvement. Primarily as a result of addressing aspects that require attention, and generally as a result of maintaining a standard, and attention to detail. He contends the H&S improvement manifests itself in a reduction in the direct and indirect cost of accidents as a result of a reduction in the number and severity of incidents. Nee, a GC H&S Manager (Smallwood, 1995b) maintains competitions complement H&S as they result in focus on specific objectives and incorporate recognition. Coy, an international South African based GC Managing Director simply says, "I am sure that they do encourage correct practices." (Smallwood, 1995b).

During the study conducted among South African general contractors (GCs) a 'Chi-square' correlation test determined there to be a statistically significant relationship between cited improvement in H&S performance and both H&S competitions, and H&S star gradings (Smallwood, 1995b).

1.6 H&S Inspections

Rozel (1992) maintains H&S inspections are a key element of an H&S programme. Minetos (1989) concurs and says that regular H&S inspections are the key to eliminate hazards and Bradford (1989) cites the proposal of the American National Standards Institute (ANSI) which calls for, inter alia, daily inspections.

The AGC (1990) recommend that regular H&S inspections should be an assigned duty of in-house H&S personnel, as inspections keep H&S at the forefront and ensure a high degree of compliance with contractor H&S rules. They maintain that supervisors should be required to conduct H&S inspections, which entail observation, identification of hazards and consequently correction of H&S hazards.

The Occupational H&S Act (OH&S Act) (1993) requires that H&S Representatives inspect the workplace including any article, substance, plant, machinery or H&S equipment at intervals agreed with the employer.

1.7 Focused H&S inspections

The Occupational Safety and Health Administration (OSHA) in the USA found that 90 percent of construction fatalities resulted from four specific types of construction accidents: falls from elevations (33%); struck by hoisting equipment, vehicles, or falling objects (22%); caught in or between i.e. trenching, cave-ins, or being crushed by equipment or other means (18%); and electrical shock (17%) (Lawrence, 1995). Consequently on 1 October 1994 the policy of focused inspections became effective. Focused inspections will focus on the four leading causes of accidents enabling inspectors to visit more sites. OSHA's new focus construction policy covers programmed (scheduled) inspections, H&S referral inspections, and fatality and complaint inspections.

Only sites with an effective H&S programme and a competent person responsible for it will be eligible for a focused inspection. The scope of the inspection may be expanded should the OSHA inspector discover poor working conditions that may indicate other problems.

1.8 Benefits of H&S inspections

During the study conducted among South African general contractors (GCs) a 'Chi-square' correlation test did not determine there to be a statistically significant relationship between H&S inspections and cited improvement in H&S performance. However, H&S inspections appear to have an influence on such cited improvement (Smallwood, 1995b).

1.9 Auditing

Rowlinson (1997) says the objective of auditing is to monitor the performance of H&S systems, the scope and timing varying according to need. According to The Building Advisory Service of H&S Technology and Management Ltd. (HASTAM) (Rowlinson, 1997) auditing is the process of collecting independent information on the efficiency, effectiveness and reliability of the total safety management system, and drawing up plans for corrective action. Although audits may or may not be conducted by independent agents they should always be conducted objectively. Output should include a report of current levels of conformance and a series of recommendations for future improvements and initiatives. In extreme circumstance immediate action may be required.

HASTAM advocates two complementary approaches to auditing, namely the 'vertical slice' and the 'horizontal slice' approaches. The 'vertical slice' approach involves looking at all aspects of a particular activity e.g. eye protection, and examining each of the key elements in the H&S management system with respect to that activity. The 'horizontal slice' approach involves looking in detail at one of the key elements in the H&S management system and determining how adequate it is, given the risks being dealt with. This is the technique used when information is required on, for example, the effectiveness of planning. Hofman (1987) maintains not having an auditing system constitutes a failure of management.

2 Research

The results of evaluations (inspections) conducted on 47 sites and facilities managed by members of the East Cape Master Builders and Allied Trades Association (EC MBA) were evaluated. The evaluations were based upon performance in the three main elements of administration, housekeeping, and general safety.

The administration element includes: general administrative legislated requirements; H&S Representative and Committee legislated requirements; first aid legislated requirements, and registers. The housekeeping category includes: signage; scaffolding; edge and opening protection; support work, and general housekeeping per se. The general safety category includes: personal protective equipment (PPE); electrical and general tools; health and hygiene, and miscellaneous.

Notification to the Department of Labour (DOL) of intention to commence construction work, availability of the OH & S Act on site, registration with a compensation insurer, appointment of competent persons, conclusion of mandatory agreements with subcontractors, appointment of H&S Representatives and the execution of their duties, compliance with first-aid requirements, and the management of registers represent management commitment, the existence of systems and a systematic structured approach to H&S.

The conclusion of mandatory agreements with subcontractors and the appointment of competent subcontractor persons are critical aspects in construction H&S as they indicate to subcontractors the integral role of H&S in the construction process. Registers facilitate a systematic procedural approach to H&S and the elimination of unsafe practices and hazards. Ultimately, the review of registers is the most elementary means of auditing the H&S management system of any contractor as registers should indicate and provide a record of the steps taken.

Although the observations relative to the general housekeeping and general safety sub-elements constitute the 'acid test', the administration sub-elements are essential to assure a healthy and safe workplace.

26 sites and facilities were 'non-competition' and 21 were 'competition' entries. The sites and facilities are further categorised according to their type: project value; allied industry; production facility; workshop/storage, and raw materials. Table 1 schedules the overall and element scores for the 'non-competition' entries.

The overall average score of 57,3% attained by non-competition entries indicates a need for increased overall effort. The administration element sub-elements are system, procedure, delegation and control orientated and play a critical role in assuring and improving H&S, and engendering accountability. Consequently the low average score for the administration element (42,4%) and the average scores for the elements of housekeeping and general safety elements amplify the need for increased focus on the administration element (Table 1).

Table 1 - Overall and element scores for 'non-competition' entries.

No.	Category	Overall score (%)	Element score (%)		
			Admin	H/keeping	G/safety
1	≥R0.5m <R2m	30.4	8.3	23.8	59.0
2	≥R0.5m <R2m	44.4	34.2	43.4	55.5
3	≥R10m <R20m	65.0	65.0	70.8	59.3
4	≥R10m <R20m	51.9	56.0	41.6	58.0
5	≥R10m <R20m	39.2	9.5	60.0	48.0
6	≥R2m <R10m	48.2	6.5	57.5	80.6
7	≥R2m <R10m	67.4	60.5	67.0	74.6
8	≥R2m <R10m	80.8	76.4	81.8	84.3
9	≥R2m <R10m	49.0	33.4	60.3	53.3

10	≥R2m <R10m	39.0	15.3	40.7	61.1
11	≥R2m <R10m	36.0	7.6	50.0	50.3
12	≥R2m <R10m	57.1	40.4	54.3	76.6
13	≥R2m <R10m	36.4	31.0	45.0	33.3
14	≥R2m <R10m	75.5	51.8	83.3	91.3
15	≥R2m <R10m	73.6	58.3	81.2	81.4
16	≥R2m <R10m	70.3	67.8	65.8	77.4
17	≥R2m <R10m	58.0	48.4	78.3	52.8
18	Allied	45.0	24.4	44.3	66.3
19	Production	58.1	50.0	65.0	59.2
20	Production	48.9	30.2	56.2	60.3
21	W/Storage	53.4	42.2	58.3	59.7
22	≥R2m <R10m	80.0	77.4	84.3	78.3
23	≥R2m <R10m	58.3	45.0	65.0	65.0
24	≥R10m <R20m	54.1	40.2	57.0	65.0
25	Allied	54.3	38.0	60.0	65.0
26		58.1	41.0	58.4	75.0
Ave		**57.3**	**42.4**	**62.1**	**67.6**

Table 2 schedules the overall and element scores for the ‘competition’ entries. The relatively high overall average score of 76,5% attained by ‘competition’ entries is primarily attributable to consistently high average scores for all three elements. The relatively high average score for the administration element (74,3%) is a manifestation of management commitment to the system, procedure, delegation and control orientated sub-elements which is essential to realise a high score for the housekeeping and general safety elements and sub-elements. It should be noted that competition evaluations are conducted on an unannounced basis.

Table 3 schedules the average percentage score for all categories for ‘non-competition’ and ‘competition’ entries. Although the sample size for most categories is small, trends can nevertheless be deduced. With the exception of ‘storage / yard’ all ‘competition’ entries attained a higher average score than ‘non-competition’ entries for every category.

With the exception of the ‘>R20m’ category in the case of ‘competition’ entries and the ‘≥R10m <R20m’ category in the case of ‘non-competition’ entries the average percentage score increased commensurately with the size of project.

Table 2 - Overall and element scores for 'competition' entries.

No.	Category	Overall score (%)	Element score (%)		
			Admin	H/keeping	G/safety
	≥R0.5m <R2m	85.4	92.5	81.3	82.4
2	≥R0.5m <R2m	47.1	8.7	55.0	77.7
3	≥R10m <R20m	61.1	65.2	59.0	59.0
4	≥R10m <R20m	86.0	91.5	84.2	82.2
5	≥R10m <R20m	81.3	83.3	79.4	81.2
6	≥R2m <R10m	86.3	90.3	86.5	82.0
7	≥R2m <R10m	57.0	33.0	68.4	69.5
8	≥R2m <R10m	70.8	54.0	79.0	79.5
9	≥R20m	67.4	56.4	74.3	71.4
10	Allied	63.3	62.3	64.3	63.2
11	Allied	64.9	57.3	62.3	75.0
12	Production	75.7	85.4	68.3	73.3
13	Production	82.6	85.6	80.0	82.3
14	Raw Material	81.3	85.7	80.0	78.2
15	Storage	66.1	62.0	73.7	62.5
16	Yard	75.7	76.0	76.5	74.6
17	≥R2m <R10m	79.6	77.5	78.8	82.5
18	≥R2m <R10m	65.9	79.4	50.0	68.2
19	≥R10m <R20m	81.0	85.0	79.0	79.0
20	≥R10m <R20m	74.8	75.0	79.0	70.5
21	Allied	77.4	79.0	83.0	70.2
Average		**76.6**	**74.3**	**77.1**	**78.2**

Table 3 - Average scores per category for non-competition and competition entries.

Category	Non-competition		Competition	
	Average (%)	No.	Average (%)	No.
≥R0.5m <R2m	37.4	2	66.3	2
≥R2m <R10m	56.6	15	71.9	5
≥R10m <R20m	52.6	4	76.8	5
>R20m	-	-	67.4	1
Allied	58.1	2	68.5	3
Production	51.2	2	79.2	2
Raw materials	-	-	81.3	1
Storage/Yard	80.0	1	70.9	2
All	57.3	26	76.5	21

3 Conclusions

Programmes are an essential aspect of management system as they enable a structured approach, MBO, focus and multi-disciplinary H&S contributions by all project stakeholders.

H&S competitions are a feature of most H&S programmes. They play an integral role in H&S improvement as they raise the level of awareness and engender focus by all project stakeholders.

The evaluations conducted by the EC MBA Health & Safety Advisor entailed both inspections and audits of all H&S related aspect and systems respectively.

The generally higher scores attained by the 'competition' entries relative to the 'non-competition' entries bear testimony to the role of competitions in raising the level of awareness.

Participation in competitions also reflects management commitment to and prioritisation of H&S. The benefits of participating in competitions is substantiated by the findings of previous research conducted in South Africa, namely that there is a statistically significant relationship between cited improvement in H&S performance by GCs and participation in H&S competitions, and by the overall average score attained by the 'competition' entries evaluated by the EC MBA H & S Advisor.

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Tools and Equipment – Their role in accident causality

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Abstract

This paper presents aspects of the results from a three-year UK Government-funded research project investigating accident causality, ConCA. The project has studied 100 construction accidents through focus groups, site audits, interviews with involved persons and follow-up along the causal chain. This paper concentrates on the influence of construction tools and equipment which were found to be major contributory factors identified by the research. They have largely been overlooked by previous studies and are not typically acknowledged as contributory factors. This paper argues for further work to confirm these links and for the inclusion of tools and equipment in the list of categories in statutory reporting procedures. This would also require an increased acknowledgement by construction managers of their influence, leading to better design and management of their supply and care on site.

Key Words

Accident causality; tools; equipment; PPE

1 Introduction

Are accidents really accidental or are they ‘caused’ by something. Most experts concur with the latter view, although there are differing opinions regarding the nature of causes and their relationship (eg Whittington et al, 1992; Abdelhamid, T.S., and Everett, J.G, 2000; Suraji et al, 2000). A full discussion of these approaches is outside the scope of this paper, however, there is no doubt that the most appropriate approach is to accept multiple causality (Reason, 1990). This paper is arguing that tools and equipment should be included in these multi-causal influences although they are often missed in accident reporting regimes.

A team from Loughborough University has just completed a three-year project funded by the UK Health and Safety Executive (HSE), the Government body responsible for health and safety. The ConCA project has been studying accident causality in the construction sector. Preliminary results have been published elsewhere (Hide et al, 2000, 2001, 2002). The ConCA project emphasis has been on an holistic, qualitative study of accident causality, concentrating on depth over breadth and recognising that there is a montage of proximal and distal factors in construction accidents. The 100 accidents studied were used as a platform to explore the spectrum of causal factors which, by their nature, become less 'hard' the further they are away from the incident. The clear intention was not to lay blame, but rather to investigate possible causes and influences relating to each accident. The measure therefore, was not 'beyond reasonable doubt', but rather 'with reasonable confidence'. The ConCA method included review, focus groups, incident identification, site inspection, site interviews, preliminary report, independent review, follow-up, analysis and incorporation of the findings within the overall causality model.

The project has delivered a detailed report to the funder, HSE, identifying a number of causal factors under the following headings:

- Worker factors
- Site factors
- Materials and equipment factors
- Underlying causes

A full discussion of these results is outside the scope of this paper, which concentrates on the tools and equipment factors.

2 Materials, tools and equipment issues raised by the focus groups

2.1 Focus group method

The aim of the focus groups was to consult stakeholders in the construction industry, exploring where failure occurs and why accidents still happen. A focus group is a style of group interview whereby the data obtained arises from the interaction and discussion generated from within the group (Morgan and Krueger, 1998). Groups are guided by a moderator, with a style that can be more or less directive, depending on the nature and purpose of the investigation. A degree of caution interpreting focus group findings is required. For example, groups may generate a level of conformity and acquiescence, suppressing individual views that might be felt in private. Alternatively, the researcher may direct discussion into an area unimportant to participants, or achieve this through data interpretation. Nonetheless, focus groups are an established method for gaining insight into views surrounding a research question.

Each group lasted about 1½ hours. Audio recordings were made of each focus group to permit subsequent transcription. An abridged transcription was made from each audiotape, recording the main points made as each participant spoke. This included a number of quotes where these were clear and salient points. To facilitate interpretation of the transcriptions, intermediate analyses were undertaken which involved summarisation of all text into short bullet point statements. These were a subjective interpretation by the researcher of the main points of what the speaker was saying. This enabled significant points to be extracted and permitted later comparison and categorisation of information according to the discussion area headings and sub-headings.

2.2 Focus group findings on tools and equipment

Although it was generally acknowledged that, where provided by the Principal Contractor, tools were often good and new to each site, it was indicated, that their selection is too cost motivated and that they were not always freely available.

Equipment was reported as not always being of a good quality and that there were problems with the selection of the correct capacity tooling and providing adequate maintenance (directed to lifting equipment). There were some concerns about the unknown quality of equipment that was used by sub-contractors and of the use of multi-functional equipment. One example, relevant to sub-contractor tool-use, was that, to compensate for unknown site circumstances, they are known to bring their largest capacity equipment to site, and proceed with using this although the equipment may in fact be too large for the task.

Availability and use of personal protective equipment (PPE) was reported to vary widely. The impression gained was that for larger companies there were plentiful supplies, but for smaller companies availability was limited and in some cases operatives were expected to provide their own PPE. It was acknowledged that non-use of correct PPE does occur and, although this is more likely to happen at the week-end, use was seen as an individual's responsibility. It was indicated that those advocating the use of PPE do not adequately appreciate the practicalities and negative influence upon performance from its wear. For example, loss of mobility; helmets that impede vision and fall off unless secured by ear muffs; and goggles that steam up frequently interrupting work in order to clean them.

3 Tools and equipment issues raised by the accident studies

3.1 Accident study method and sample description

The study method for the 100 accidents can be summarised as follows:

1. Obtain details of the incident and evaluate against sample frame
2. Visit site and interview involved persons
3. Interview supervisors, managers, H&S staff (as appropriate)
4. Draft initial study report
5. Review report by independent expert panels to identify potential follow-up
6. Follow-up studies (generally off-site)
7. Complete accident study report

Table 1 provides a breakdown of the accidents studied by construction sector. It can be seen that major building and civil engineering were over-represented, while the residential sector was under-represented against the original targets. Nevertheless, the table shows that the accidents occurred across the range of industry sectors.

Table 1 Distribution of the accidents studied (n=100)

	Engineering construction	*Civil engineering*	*Major building*	*Residential*
Target	5	15	45	35
Result	4	25	49	22

There was wide variation in the nature of build and organisational details of participating sites, ranging from short contract work to major building projects, being undertaken over a number of years. All but 16 of the sites were brownfield (4 unknown/missing data). Sites varied considerably in size, accommodating between 7-

2500 personnel and with build schedules varying between 1 week to more than 10 years. From the 100 accidents, 71 projects were reported to be running to time, 1 was ahead and 18 were behind schedule (10 unknown/missing data). Four of the sites were undertaking concurrent phases of their work, whereas 11 were in the 'start' phase, 58 in the 'middle' phase, 9 between 'middle' and 'end' phases, 7 in the 'end' phase and 2 in the 'after' phase (9 unknown/missing data). 4 projects included refurbishment activities. Many of the main UK principal contractors were represented. The contract types were as follows:

- design and build / contractor led – including residential developers (n=31)
- integrated eg partnering / PFI / alliancing (n=24)
- lump sum / fixed price / design then build (n=14)
- construction management (n=13)
- other contract types (n=4)
- unknown i.e. not identified in the accident study (n=14)

3.2 Accident circumstances

Based on the accident book entries, twelve of the 100 accidents should have been reported to the authorities under UK regulations (but were not necessarily actually reported as such). Of these, three were dangerous occurrences, eight resulted in absences of over 3 days and one was a major accident. The accidents were grouped according to HSE categories (Table 2) (revised to combine slips, trips and all falls data together) with an additional category for 'injuries directly involving materials, tools or equipment' as this was found to be an important category that is not currently included by the authorities. 12 of the accidents were included in this category.

Table 2 Distribution of accident types (n=100)

Category	*Accidents number reported*	*Total*
Slips, trips and falls (all levels)	16, 17, 23, 36, 37, 46, 47, 51, 53, 54, 55, 58, 62, 64, 73, 75, 77, 81, 86, 88, 100	21
Injured while handling, lifting or carrying	5, 14, 15, 28, 29, 31, 33, 34, 38, 39, 48, 50, 56, 57, 76, 83, 84	17
Struck by moving (+ flying / falling) object	1, 4, 9, 19, 24, 32, 35, 43, 44, 61, 63, 68, 69, 78, 89, 93, 96, 97	18
Injuries directly involving materials, tools or equipment	7, 26, 30, 49, 59, 74, 80, 87, 92, 95, 98, 99	12
Strike against something fixed or stationary	6, 18, 21, 22, 25, 27, 82, 91	8
Dangerous occurrences	3, 10, 11, 20	4
Contact with/by moving machinery	2, 12, 13, 42, 85	5
Trapped by something collapsing or overturning	60, 65, 70, 72, 90	5
Contact with electricity or electrical discharge	52, 71	2
Other accident events types	8, 40, 41, 45, 66, 67, 79, 94	8

Following the studies, the pattern of involvement of tools, equipment, materials and site / structure, along with the nature of the task or activity being undertaken at the time of the accident were analysed (Table 3) showing that 28 accidents involved plant or equipment and 17 involved tools.

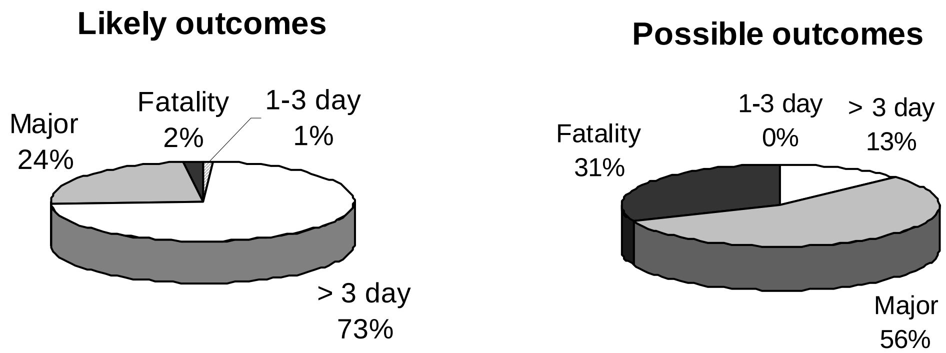
Table 3 Activities and involved items within the accident sample (n=100)

	Tools	*Plant / equipment*	*Materials*	*Site / structure*	*Total*
Setting-up		31, 42, 74	34	16, 67, 73	7
Actual task activity	2*, 3, 7, 13, 14, 26, 30, 39, 49, 59, 65, 87, 89, 97, 99	8, 11, 29, 38, 60, 71, 94, 79	5, 9, 10, 15, 33, 35, 40, 43, 45, 48, 57, 63, 80, 84, 95, 96	20, 24, 27, 28, 52, 55, 58, 61, 77, 78, 91, 92, 93	52
Clear-up / maintenance	98	4, 12, 21, 32, 46, 56	54, 66, 70, 83	82	12
Movement / transit	50	6, 17, 19, 22, 36, 37, 41, 51, 62, 85, 90	1, 25, 44	18, 23, 47, 53, 64, 68, 69, 72, 75, 76, 81, 86, 88, 100	29
Total	17	28	24	31	100

3.3 Accident consequences

The limitations on the accident sample meant that most of the accidents studied had outcomes that were not reportable under the UK regulations (RIDDOR). To consider the significance of the research findings an exercise was completed to propose potential outcomes (Figure 3). These have been established as ‘likely’ and ‘possible’ based on the RIDDOR classification. This rationale relies on an evaluation of the incident information and evaluation of alternative outcomes if the injured person had been in a slightly different location or if a different part of the body had been involved. Likely outcomes require only a minor change in circumstances; possible outcomes would require a number of circumstances to change for them to occur. Some of the ‘major’ incidents may have led to permanent disability and hence loss of the individual to the industry. With a modest change in circumstances, it is likely that almost three-quarters of the accidents could have resulted in absences of more than three days and almost a quarter could easily have been major incidents. It

uld have resulted in fatalities. With a



3.4 Analysis of causes

Following the completion of the 100 accident study reports, further analysis was performed by the researchers, based on their judgement of 'reasonable confidence' that a factor was causal in an accident. It should be borne in mind that is easier to be confident concerning the involvement of more immediate factors, eg worker actions or site hazards, than wider influences, such as safety culture. This is because the action of the immediate factors is direct and more obvious, while the involvement of other influences is more subtle. A summary of the findings from this analysis is presented in Table 4 with 56 accidents now being found to be linked to tools and equipment.

Table 4 Summary of accident causes

Category	Causal Factor	Number of accidents	
Worker & Work Team	worker actions/behaviour	49	70
	worker capabilities (including knowledge/skills)	42	
	communication	7	
	immediate supervision	13	
	worker health/fatigue	5	
Workplace	site conditions (excluding equipment, materials, weather)	11	49
	site layout/space	15	
	working environment (lighting/noise/hot/cold/ wet)	9	
	work scheduling	11	
	housekeeping	19	
Materials	suitability of materials	12	27
	usability of materials	8	
	condition of materials	13	
Tools and Equipment	suitability of tools or equipment	44	56
	usability of tools or equipment	19	
	condition of tools or equipment	12	
Originating Influences	permanent works design	27	94
	project management	24	
	construction processes	12	
	safety culture	15	
	risk management	84	

3.5 Tools issues from the accident studies

An assortment of tools featured in the accident studies, ranging from simple hand tools through to more sophisticated or powered tooling. Shortcomings in function or performance were reported by interviewees, with further problems with tool design observed by the researchers. Typical failings included poor grip characteristics, undesirable pressure at skin contact points and, for powered tools, frequent use of finger trigger operation. Some tools also appeared heavy, given the situations in which they were being used. For example, the petrol saw and torque multipliers used in two of the accidents each weighed 11.5kg and 8.9kg, heavy loads when used in awkward postures. It was observed that attempts to reduce problems with tools had been made by users through the addition of padding or tape on handles. Bladed tools required frequent unprotected handling of the cutting edge to change blades or to remove obstructions. One accident involved an electrocution due to problems with the performance of a CAT scanner. Time saving seemed to be an issue in tool use for other accidents.

A kerb lifter is available, but by the time you get it it's easier to use two people at each end... …The saw was quite a heavy and bulky tool for cutting the pipes, but a handsaw would have taken forever …

Interesting comments were made about criteria for tool purchasing. The self-employed often provided their own tools, although it was also reported that self-purchase was sometimes preferable anyway due to the poor quality and condition of equipment supplied on site. In describing factors affecting their purchase choice, most interviewees seemed to aim for a 'middle of the road' price and selection according to manufacturer.

… Tools in the £15-40 price range are all pretty much the same …

Tool pricing was a concern for many, especially when the tools were vulnerable to theft, or had a short life-span. In one case the tool performance (non-rusting) was referred to as a purchasing criterion. Interviewees obtained their tools from a specialist supplier or through mail-order catalogues. Some interviewees had been trained in use and care of their tools, but rarely since their apprenticeship. Others felt that they had just picked it up as they went along or relied solely on suppliers' information. Instructions were sometimes considered unhelpful and left unread.

3.6 Equipment issues from the accident studies

Equipment, including machinery or plant brought onto site, was identified as deficient in more than half of the accident studies and in all cases was directly involved in the adverse incident. Failures relating to equipment included problems resulting from inadequacies in dimensions for user anthropometry or with the user interface. These problems were further compounded by shortcomings in performance, maintenance and safety-related features. Inappropriate physical dimensions of some equipment resulted in user interaction, such as physical or visual access, being hampered. In one accident a jump was required to climb off a scissor lift. Inspection of the equipment revealed that there were no distinct handholds on this equipment to support the user in this action.

… We're taught to come down the scissor lift steps backwards, but the last step is about 2ft from the ground, so you have to jump the last bit …

The safety cage on top of the scissor lift offered the most convenient points to grasp (at 2.2m from the ground), yet fixing bolts here were left exposed, compromising the only handhold available. A related problem occurred in connection with the length of ladder attached to the side of a rail wagon (Figure 4). Elsewhere, use of split or cut down ladders was reported.

Figure 4 Ladder access to rail wagon

In a similar context, problems were identified with the use of scaffold towers. In some instances difficulties may be experienced in achieving a desirable scaffold and handrail height for the work requirements, given the fixed height scaffold components available. Another example, commented upon spontaneously by interviewees in a number of accident studies, concerned the small size of access opening between different scaffolding levels. This access space is frequently too small for larger individuals, or those that might be carrying items about their person.

Problems had also arisen with operations involving manual movement of loads. In one case, load instability existed due to free movement of fuel within a fuel bowser. In one accident, problems occurred manoeuvring a laden plasterboard trolley (Figure 5). The trolley had directional wheels at only one end (the other end having fixed forward facing wheels). While it was not known which end of the trolley was leading, difficulties were to be expected moving a full load with this particular trolley design.

IP's hand was crushed against an adjacent scaffold handrail whilst removing plasterboard sheets from a fully loaded trolley.

Figure 6 Plasterboard trolley

Equipment maintenance deficiencies featured in several accidents, especially with respect to steel parts (such as scaffold clips, concrete pipe clams and extendable steel props). Weathering and concrete were reported as the main antagonists. Although 'regular cleaning and maintenance programmes' were in place, overcoming rust and similar problems added to the physical effort required to use equipment. Examples were found where the design of equipment gave little heed to its usability or how the user might detect and monitor different states. One accident involved an operative, whilst maintaining a crawler-mounted crane, falling from the running boards as the handle from the maintenance hatch gave way. Lack of feedback (eg visual, auditory or tactile information to the user) status of the equipment was a factor in several accidents. One accident involved a fire caused by an electrical fault on a pneumatic breaker which the supervisor considered had been caused by misuse of the equipment, but this damage had not been obvious to the operatives involved.

Usability issues were reported, for instance in the overturning of a delivery lorry where the interviewee described the wide range of lorry types he used in his work. There were common features however, such as the crane controls, but it was apparent that their design contravened user expectations (pushing the lever down raised the crane and vice versa). It was also reported that safety protection features built into the equipment did not anticipate this particular accident event.

Suitability of equipment was an issue in a number of accidents, where machines were being used for activities other then their primary purpose (eg excavator and forklift used instead of crane).

3.7 Personal Protective Equipment (PPE) issues from the accident studies

Use of a safety helmet, high visibility vest and safety boots was mandatory on all sites visited, with supplementary use of protective eyewear, gloves, harnesses and respiratory protective equipment (RPE) expected depending on task type. Adverse comments were made about PPE in a large number of the accident studies. Criticisms related to poor fit and comfort; inappropriateness for actual task requirements; poor quality, care or condition; problems with availability and excess cost.

Comments concerning safety helmets focused on their frequent poor fit and comfort. Remarks were made about the lack of lining or padding, insecurity (due to lack of a chinstrap), poor ventilation (especially in summer) and being too small. Interviewees reported that helmets were regularly dislodged or fell off, induced headaches and interfered with work on looking up. In two of the accidents the injured persons' helmet fell off when they bent down, both then struck their head on something when they stood up.

Many interviewees accepted or were resigned to wearing a safety helmet, seeing them as a 'necessary evil' and in a number of the accidents helmets helped to reduce the extent of the injury. However, it was also said that they are not always needed, with some frustration at the lack of flexibility over when helmets needed to be worn.

… With the hat you're more likely to hit your head, as you don't account for the extra height when walking underneath different structures …

In many of the accidents where the hands were at risk, the injured person was not wearing protective gloves. There were also complaints about the comfort and fit of gloves, with operatives not wearing them as they interfered with ability to operate tools and the speed with which they could undertake their work. Operatives reported inadequate supplies of gloves (necessitating use of worn out protection), inadequate durability and lack of a suitable size range. There were also reports that gloves are frequently mislaid with constant taking off and putting on. In some cases the gloves worn were not adequate to provide protection from the risk.

Fall arrest harnesses were discussed in a small number of accident studies (only specified trades require use of this PPE), yet among those who were in a position to comment, there was a consensus of criticism about the equipment. These included complaints about comfort and fit (especially when used for longer than 30 minutes), concerns about restriction of mobility and inadequate supplies (leading to harness hoarding among site operatives). Interviewees were also worried that the 2-metre lanyard length was inadequate and that they would experience physical injury from the harness itself should they experience a fall. As with other PPE, it was acknowledged that harness use was necessary, but interviewees felt that they should be permitted greater discretion over when to wear fall arrest equipment

With regard to other PPE, protective eyewear was said to steam up and cause difficulties when performing certain tasks and under particular lighting conditions. There were problems with protective eye-wear for those needing to use 'prescription' glasses, although suitable prescription safety glasses are available. RPE users mentioned problems with fatigue and being impeded when undertaking certain operations. There were some complaints about high-visibility vests, concerning the obstruction they pose when trying to access tools from waist belts and a lack of fabric breathability, causing discomfort in hot weather.

Many interviewees reported having to buy their own protective footwear and in one case another reported purchasing his own protective eyewear. Interviewees reported receiving little instruction as to the maintenance of their PPE, although when asked about this respondents thought that care was ‘down to the individual’, or instruction unnecessary as they had used it for a long time.

Interviews with supervisor/managers indicated that PPE and its availability were viewed differently than by those in operative grades. These respondents were concerned about the lack of care given to PPE, with reports of finding new and expensive PPE treated badly, left lying around or improperly looked after. Ordering and choice of PPE was in a number of instances undertaken by ‘Head Office’ although in other cases supervisor/managers were involved. Only a few had tried ordering new styles, prompted by recommendation, observation of use by other construction teams, or through information provided in supply catalogues. One interviewee reported working with glove manufacturers to trial new products and another, in the case of a new short peaked hat, had tried it themselves to assess the product.

4 Conclusions

The ConCA project has shown that tools and equipment, including PPE, were a major causal factor in the 100 construction accidents studied and that this number increased as a closer study along the causal chain was completed (Accident book 12; initial site-based study 45; further analysis 56).

ConCA argues that a category should be added to the statutory reporting procedures to record the involvement of tools and equipment in accidents. In this way their contribution to accident causality can be properly evaluated. In the meantime, all involved in the construction process should look to improve communication and feedback loops with tools and equipment designers and suppliers. All involved should carefully evaluate tools chosen and ensure that lowest cost is not the main criteria for their selection. Managers and operatives alike should ensure that tools and equipment and well maintained and replaced frequently.

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Occupational Safety and Health Management System in the construction of roads: The owner's perspective

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Abstract

The Portuguese Road Institute (IEP) is the public entity responsible for the construction of new Portuguese roads, which includes bridges, viaducts and other infrastructures. It is also responsible for maintenance and operation of all Portuguese roads.

Typically, about 50 new projects are under construction each year, involving an investment of about 1,5 billion Euros. For the construction of all these projects, occupational safety and health is a very important issue and the Construction Sites Directive 92/57/EEC (CSD) is being implemented based on an OSH management system specifically developed by IEP – the owner.

According to the CSD, this management system covers the design phase, the construction phase and also the rules on safety and health to be taken into account during the use of the final construction product. All stakeholders in each construction project (designers, safety and health coordinators, supervisors, contractors), are obliged to follow this management system, as they are part of the specifications. The aim of this paper is to present this management system, which is being implemented in many construction projects, and to discuss and share this experience with experts from different countries, so that there can be a continuous improvement of this system.

Keywords

Road construction; construction safety and health; management system; case study

1 Introduction

The Portuguese Road Institute (IEP) is the public institute in Portugal responsible for the planning, construction, maintenance and operation of all roads. It is responsible for the maintenance of more than 15.000 km of roads and builds in average 60 km of new roads every year. Being one of the greatest Owners in Portugal, occupational safety and health is a very important issue and an objective to accomplish.

This paper focuses essentially in the construction area of the IEP, being the most problematic issue concerning occupational safety and health.

It reports the way IEP was restructured and the mechanisms which have been used to comply to EEC Directives 92/57/EEC and 89/391/EEC, and insure an effective coordination between safety and health during the preparation of project and the execution of the contracts, taking into account the defined quality level and appropriated time schedule and costs issues.

2 The Portuguese Road Institute (IEP) and the Safety and Health in Construction

IEP invests more than 1,5 billions Euros per year, divided between Design, Expropriation, Construction, Maintenance and Public Services Conceded. From this investment, more than 300 million Euros go towards the construction of new roads.

At the moment, IEP has more than 2000 workers distributed among different sectors. Of those, about 350, are in the construction area.

In the Maintenance and Operation area, the Institute is divided into 17 «Road Departments», and the Construction area is divided into 7 «Project Management Departments».

In the Construction area, IEP decided to create the Safety and Health Department (SHD) in January 2001, aiming to implement in all projects a safety and health management system, so that all activities can be performed under good safety and health conditions at the working place.

The SHD of IEP has two experts on safety and health and each Project Management Department (PMD) has an additional expert on safety and health. In addition, the Design and Technical Support Department (DTSD) has two other experts in that field - one responsible for the sector of roads and the other for sector of bridges and viaducts.

All these experts are graduated in Engineering (mostly in civil engineering) and have a complementary training in “Safety and Health on Construction Sites: Management and Coordination”, held for this specific field.

Internally, the organisational structure of the construction area of IEP is as showed in the following Figure 1.

The Safety and Health Department (SHD) mission includes: the technical support on construction safety and health to the “Design and Technical Support Department” (DTSD) and to the “Project Management Departments” (PMD); preparation of technical procedures, rules and clauses; compilation of information, training and information actions; relationship with external entities; preparation of quarterly reports and realisation of safety and health audits at DTSD (during the design development) and PMD (during the construction phase).

In addition, the SHD have the following competencies: to support the Board of Directors of IEP; to represent IEP in events; regulation within the IEP on this subject; coordinate training and information of all the workers of IEP in regard to safety and health on construction sites.

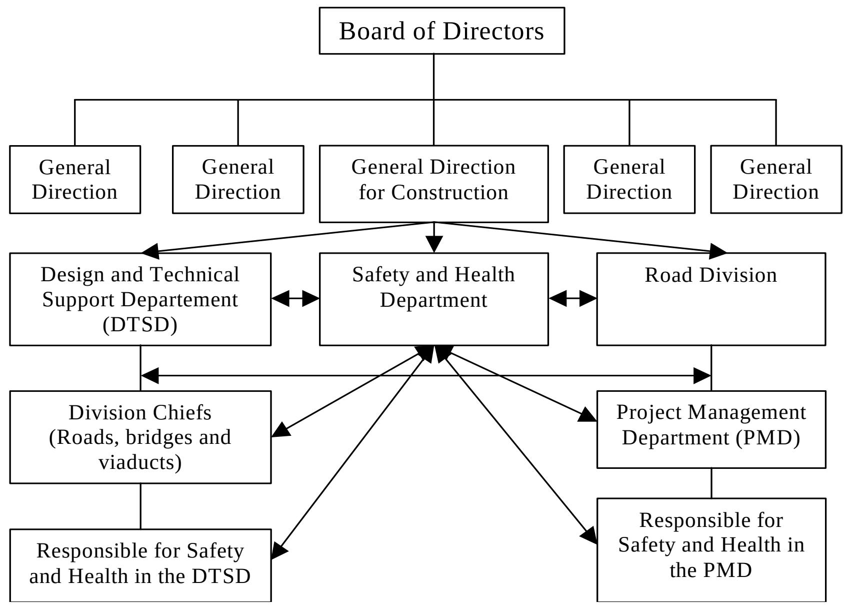


Figure 1 – The Organization structure of the construction area of IEP

One of the main goals was achieved in September 2001, when the preparation of the "Manual for the Implementation of Safety and Health on Construction Sites" (MSHCS) was started. It was completed and promulgated in March 2002. Technical support was provided from an external expert in the preparation of this Manual.

As a methodology, it was decided to involve all the design and project managers of IEP. Therefore, the SHD, together with the external expert, promoted a series of meetings during this period, with the Board of Directors, the directors of all the different departments, namely the DTSD, PMD and Legal Department.

In spite of the fact that the management system and the Manual were only implemented in March 2002, IEP through the SHD, has been promoting training sessions since early 2001, for the workers of IEP and the different participants in the construction process.

3 Safety and Health Management System on Construction Sites

The MSHCS contains the organizational structure and job descriptions of key positions, as well as a group of general rules that should be followed by DTSD and PMD. This Manual includes the following documents:

a) Declaration of the Safety and Health Policy of IEP for the construction of road projects;
b) IEP organizational structure and job descriptions;
c) Model of Prior Notice;
d) Specifications for the competition of designers;
e) Specifications for the competition of supervising companies;
f) Specifications for the competition of contractors;
g) Reference model for Safety and Health Plans;
h) Reference model for Safety and Health Files;
i) Guidelines for DTSD reports;

j) Guidelines for PMD reports;
k) Guidelines for SHD reports.

The IEP's declaration of Safety and Health Policy for the construction of road projects, which is supported by the MSHCS, was based on the following crucial principles, that should be observed by all those involved in the construction process at all levels:

- Due compliance with all legislation in regard to safety and health in the construction of IEP road projects in all phases, assuring an effective coordination of safety and health during the design and execution of the works, conjugated with the defined quality and appropriate time schedule and costs;
- Accountability of all participants in the construction of IEP road projects regarding their obligations towards safety and health in the construction phase, accomplishment of all statements of the MSHCS, and taking care of their own and other's safety and health (including the population in general) that could be injured by their actions;
- Demand of implementation of Safety and Health Management Systems on Construction Sites developed by Contractors engaged by IEP, based on MSHCS rules and according to an effective accomplishment of the obligations as regards to safety and health in the work and to the need of infusing a culture in the area of safety and health to all those involved in the construction process;
- Continuous pursuit of a tendency policy of "zero accidents" and "zero professional diseases", which demands an accurate record of accidents and working casualty indices of each company.

The organizational structure of the Institute was defined, as well as competencies, obligations and responsibilities of all participants in the process of the construction concerning safety and health.

The model of the Prior Notice was prepared in accordance to the transposition of the Directive 92/57/EEC (CSD), with two additional points that were considered important.

The specifications for the selection of designers were prepared and included in the competition process, with two options concerning the Safety and Health 's Coordination during this period, under direct IEP or under the Designer's responsibility.

The specifications for the selection of supervising companies were also prepared to be included in the competition process, which assume the coordination of safety and health during the execution phase, naming one person responsible for that coordination.

The specifications for the selection of contractors, include a group of requirements in the competition process based on IEP's responsibility of coordination for safety and health during the construction phase.

The reference model of the Safety and Health Plan (SHP) was structure as shown in the following table 1 and the reference model of the Safety and Health File (SHF) was structured as shown in table 2.

Table 1 - Structure of the reference model of the Safety and Health Plan (SHP)

SAFETY AND HEALTH PLAN (SHP)	
1. Introduction	1.1 Organization of SHP 1.2 Adaptation / complement of SHP 1.3 Identification of archives 1.4 Changes in SHP 1.5 Delivery of SHP 1.6 Organizational chart and Job Descriptions 1.7 Control of Signatures and rubrics
2. Description	2.1 Safety and Health at Work Policy 2.2 Definition of targets 2.3 Action Principles 2.4 Prior Notice and Immigrant Workers Declarations 2.5 Applicable Regulations 2.6 Work Timetable 2.7 Control of Subcontractors and related chain of subcontracts 2.8 Accidents insurance
3. Characterization of the works	3.1 Main characteristics of the work 3.2 Bill of Quantities 3.3 Local Conditions 3.4 Planning 3.5 Plan and Chronogram of the workmanship 3.6 List of works with special risks 3.7 List of materials with special risks 3.8 Work phases 3.9 Construction procedures and methods
4. Actions to prevent risks	4.1 Construction site design 4.2 Access, Circulation and road-signs Plan 4.3 Control of support equipment 4.4 Collective protection Plans 4.5 Control of materials and equipment reception 4.6 Plans and Registration of monitoring and Prevention 4.7 Registration of non-compliances and corrective/preventive actions 4.8 Identification and health control of the workers 4.9 Protection of Individuals Plan 4.10 Training and Information of the workers 4.11 Registration of accidents and indices Plan 4.12 Visitors Plan 4.13 Emergency Plan 4.14 Excavations Plan 4.15 Plan of execution of piles 4.16 Plan for forms and placing concrete 4.17 Plan for setting metal structures 4.18 Plans for pre-stress application 4.19 Plans for assemble, use and disassemble of scaffolds 4.20...
5. Monitoring and follow-up	5.1 Monthly supervising 5.2 Committee for Safety and Health at the work site 5.3 Internal audits

Table 2 - Structure of the reference model of the Safety and Health File

SAFETY AND HEALTH FILE (SHF)	
1. Introduction	1.1 Organization of SHF 1.2 Adaptation / complement of SHF 1.3 Identification of archives 1.4 Changes in SHF 1.5 Delivery of SHF 1.6 Control of Signatures and rubrics
2. Description	2.1 Objective of the SHF 2.2 Main characteristics of the work 2.3 Applicable regulations
3. Characterization of the work	3.1 Brief description of the work 3.2 Project “As built” 3.3 Local Conditions and the environment 3.4 Brief description of the underground 3.5 Registration Notebook of the work 3.6 Materials used involving special risks and preventive procedures 3.7 Quality records 3.8 Safety and Health records
4. Actions for risk prevention	4.1 Plan of periodic Monitoring, Identification and Control of support equipment 4.2 Record of non conformities and corrective/preventive actions 4.3 Training and information of staff appointed by the owner 4.4 Record of accidents in work 4.5 Emergency and evacuation Plan 4.6 Plan for access and temporary road-signals 4.7 Plan for maintenance of permanent road-signs and barriers 4.8 ….

The system was conceived in order to have a dynamic approach during the execution of the works and should integrate the projects, plans and records of all measures concerning safety and health, and should include all the construction processes and working methodology used by the contractor, the external conditionings, the construction site organization and construction planning.

The implementation of a systematic performance on a construction site intends to emphasize the obedience of contractual documents and the fulfilment of the demands of the current legislation in order to:

- do all the works in a way that assures that all the workers on the construction site have proper safety and health conditions;
- achieve good levels of productivity obtained through good working conditions;
- minimize the working casualty rates and the resulting labour and social costs;
- accomplish all works with the quality required, in a well-organized site and with an appropriated environment.

To achieve these goals, the IEP considers that actions should be based upon principles, such as:

- consider the safety at work as a part of its accomplishment;
- follow all laws and rules concerning safety and health at work;

- avoid risks and evaluate and fight against risks that can’t be avoided;
- make a plan of prevention and protection for all the activities involving risk;
- replace what is dangerous by what is harmless or less harming;
- adapt the work to the man, especially concerning the job, the equipment used, construction processes and procedures used during the work;
- give preference to the collective protection measures over to the individual’s;
- register the actions planning and accomplishment in order to emphasize its preparation and execution;
- recognize workers’ obligations and rights. These workers must be considered in the implementation of planned preventive measures;
- stimulate workers to care for their own safety and for the safety of the co-workers that could be affected by their actions;
- encourage workers to identify and communicate all the dangerous situations they face, even if they don’t interfere with their security;
- promote the necessary actions to give workers the adequate instructions, to assure they all understand them, for the good safety in work;
- allocate all human resources and materials necessary to the planned actions implementation to assure safety in work, considering the technique evolution.

4 Safety and Health Management System Implementation in Construction Sites

The system considered in the Manual was implemented in all new projects that started after the promulgation date (March 2002). As to the projects that started before that promulgation date, the system was introduced with the required adaptations whenever possible. An effort was made to adapt the Manual to the Safety and Health Plans already existing on the projects previously approved or under implementation.

In the projects already under construction, the contractors were requested to consider the application of the new system as an amendment to the existent Safety and Health Plan. It must be emphasized that all contractors accepted this amendment.

Although the Manual was implemented in March 2002, since January 2001 data was collected on the extent of the legislation compliance, and also on the number of accidents and injuries including some indices.

So, to have a clear perspective of the significant improvement achieved after the implementation of the safety and health management system on construction sites, it follows some relevant data of IEP.

The volume of construction of IEP, in million Euros, for the years 2000 to 2002 and distributed by each project management department is shown in table 3.

Table 3 – Distribution of the volume of construction (million Euros)

(Millons of euros)

Project Manegements	*2000*	*2001*	*2002*		
			Jan-Sept	*Oct-Dec*	*Total*
PM1	73	61	69	30	99
PM2	67	56	49	9	58
PM3	46,5	13	18,5	7	25,5
PM4	27	43,5	34	4	38
PM5	33,5	26,5	25	7	32
PM6	15	30,5	36	2	38
PM7	41	20,5	23,5	5	28,5
Total	303	251	255	64	319

Source:IEP

The occupational safety and health accidents and indices in IEP during the year 2001 and 2002 (Jan. to Sep.) are presented in tables 4 and 5, respectively.

Table 4 – Occupational safety and health accidents and indices (2001)

Date		Average n.º of Workers		Man*Hours Worked		Nº of accidents		Nº of days lost	Incidence Rate	Frequency Rate	Severity Rate	Duration Rate
						Fatal	Non-Fatal					
Year	Month	Month	Total	Month	Total	Total	Total	Total	Total	Total	Total	Total
2001	January	1282	1282	208377,5	208377,5	0	4	150	3,12	19,20	0,72	37,50
2001	February	1281	2563	219055,5	427433	1	9	319	3,90	23,40	18,29	31,90
2001	March	1268	3831	242388,5	669821,5	1	18	521,5	4,96	28,37	11,98	27,45
2001	April	1481	5312	260611,5	930433	1	36	748,5	6,97	39,77	8,87	20,23
2001	May	1704	7016	324471,5	1254905	1	43	1001,5	6,27	35,06	6,77	22,76
2001	June	1931	8947	366697	1621602	1	56	1213,5	6,37	35,15	5,37	21,29
2001	July	2181	11128	437519,5	2059121	2	70	1538,5	6,47	34,97	8,03	21,37
2001	August	2257	13385	430180,5	2489302	2	84	1800,5	6,43	34,55	6,75	20,94
2001	September	2582	15967	514934	3004236	4	90	1946,5	5,89	31,29	10,63	20,71
2001	October	2470	18437	533224,5	3537460	4	109	2203,5	6,13	31,94	9,10	19,50
2001	November	2649	21086	538156,5	4075617	5	116	2452,5	5,74	29,69	9,80	20,27
2001	December	2493	23579	437123,5	4512740	5	123	2655,5	5,43	28,36	8,90	20,75

IR = N.º of accidents per thousand workers = (total n.º of accidents / N.º of workers) * 1.000

FR = N.º of accidents per million man-hours worked = (N.º of accidents / N.º of man-hours worked) * 1.000.000

SR = N.º of days lost per thousand hours worked = (N.º of days lost / N.º of man-hours worked) * 1.000

DR = N.º of days lost per accident = N.º of days lost / N.º of accidents

Source : IEP - The Portuguese Road Institute

Table 5 – Occupational safety and health accidents and indices (Jan-Sept 2002)

Date		Average n.º of Workers		Man*Hours Worked		Nº of accidents		Nº of days lost	Incidence Rate	Frequency Rate	Severity Rate	Duration Rate
						Fatal	Non-Fatal					
Year	Month	Month	Total	Month	Total	Total	Total	Total	Total	Total	Total	Total
2002	January	2676	2676	508972	508972	0	11	179	4,11	21,61	0,35	16,27
2002	February	2805	5481	506420	1015392	0	24	371	4,38	23,64	0,37	15,46
2002	March	2950	8431	538782	1554174	0	40	568	4,74	25,74	0,37	14,20
2002	April	2946	11377	592305	2146479	0	52	788	4,57	24,23	0,37	15,15
2002	May	3037	14414	591198	2737677	0	63	978	4,37	23,01	0,36	15,52
2002	June	2889	17303	552856	3290533	1	71	1166	4,16	21,88	2,63	16,19
2002	July	3180	20483	637399,5	3927933	1	88	1363	4,35	22,66	2,26	15,31
2002	August	3165	23648	582081,5	4510014	2	104	1585	4,48	23,50	3,68	14,95
2002	September	3096	26744	589558,5	5099573	2	113	1840	4,30	22,55	3,30	16,00
2002	October	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00
2002	November	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00
2002	December	0	0	0	0	0	0	0	0,00	0,00	0,00	0,00

IR = N.º of accidents per thousand workers = (total n.º of accidents / N.º of workers) * 1.000

FR = N.º of accidents per million man-hours worked = (N.º of accidents / N.º of man-hours worked) * 1.000.000

SR = N.º of days lost per thousand hours worked = (N.º of days lost / N.º of man-hours worked) * 1.000

DR = N.º of days lost per accident = N.º of days lost / N.º of accidents

Source : IEP - The Portuguese Road Institute

In the following figure 2, the above indices are presented in a graph form. They emphasise the decreasing of all indices between the years 2001 and 2002, although for this last year the indices are taken for the first nine months (accumulated values).

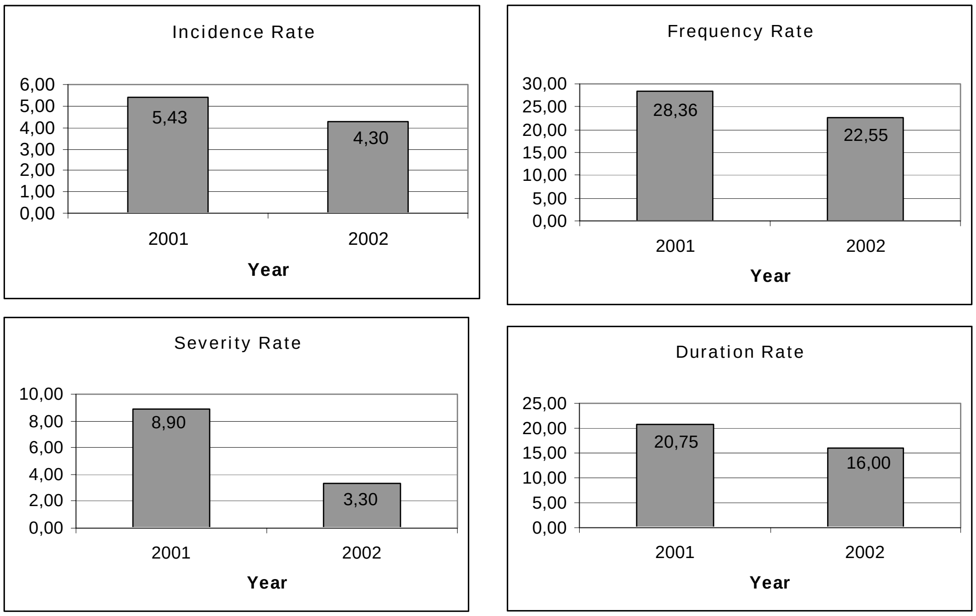


Figure 2 - Injury Rate graphics

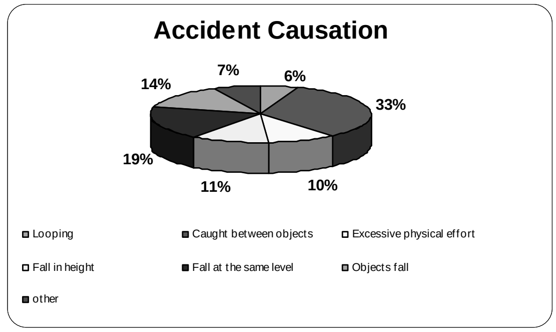
The following table 6 summarises some of the main and important information that can complement the above.

Table 6 – Summary of some information

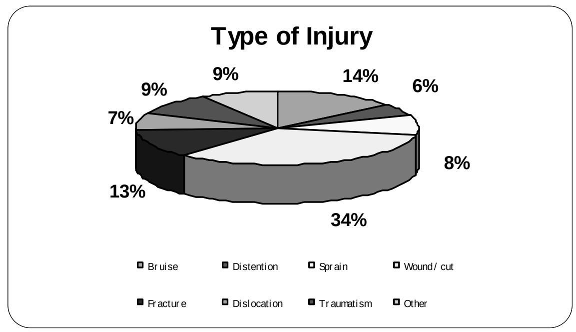
YEAR	2001	2002 (Jan. to Sep.)
Total Number of accidents	128 Accidents	105 Accidents
Millions in Euros of accomplished works / accident	2 Million Euros / accident	2,5 Million Euros / accident
Millions in Euros of accomplished works / fatal accident	50 Million Euros / fatal accident	127,5 Million Euros / fatal accident
Nº of accidents / fatal accident	25 Accidents / fatal accident	52,5 Accidents / fatal accident
Rate of fatal accidents	4 %	1,9 %
Average of workers / Month	1 965 Workers/Month	2 965 Workers / Month
Average of working hours/ Month	376 060 Hours / Month	566 985 Hours / Month
Average of working hours/ worker / Month	190 Hours / worker / Month	190 Hours / worker / Month
Average of working hours/ worker / Day	8,7 Hours / worker / Day	8,7 Hours / worker / Day

In the following figure 3, it is presented the profile analysis of some accidents occurred during 2002 including causes, type of injury and body parts affected.

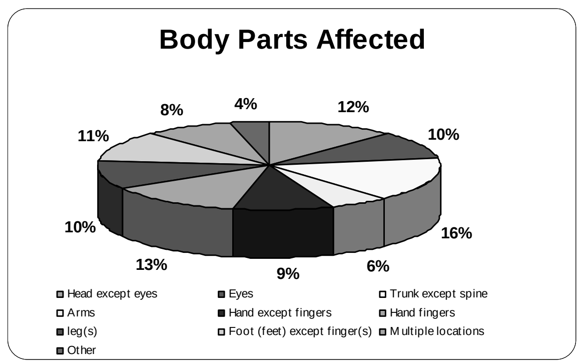
ACCIDENT CAUSATION	*TOTAL*	*%*
Looping	*6*	***6%***
Caught between objects	*36*	***33%***
Excessive physical effort	*11*	***10%***
Fall in height	*12*	***11%***
Fall at the same level	*20*	***19%***
Objects fall	*15*	***14%***
other	*7*	***7%***

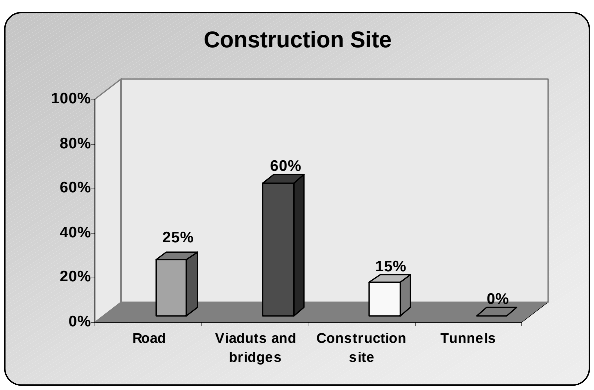


TYPE OF INJURY	*TOTAL*	*%*
Bruise	*15*	***14%***
Distention	*6*	***6%***
Sprain	*9*	***8%***
Wound / cut	*36*	***34%***
Fracture	*14*	***13%***
Dislocation	*8*	***7%***
Traumatism	*10*	***9%***
Other	*7*	***9%***



BODY PARTS AFFECTED	*TOTAL*	*%*
Head except eyes	*13*	***12%***
Eyes	*11*	***10%***
Trunk except spine	*17*	***16%***
Arms	*6*	***6%***
Hand except fingers	*10*	***9%***
Hand fingers	*14*	***13%***
leg(s)	*11*	***10%***
Foot (feet) except finger(s)	*12*	***11%***
Multiple locations	*9*	***8%***
Other	*4*	***4%***





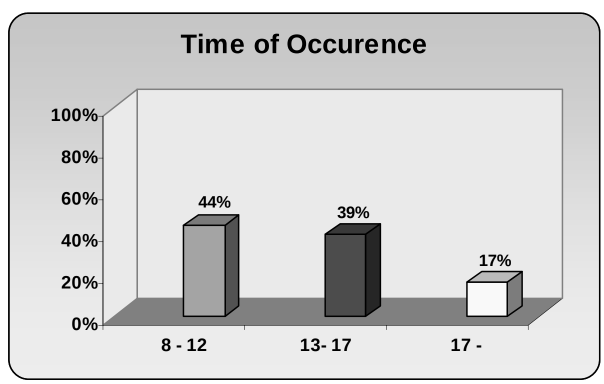


Figure 3 - The profile analysis of the accidents occurred during 2002

The analysis of the above figures indicates that caught between objects (33%) and falls at the same level (19%) were the main causes of accidents. The main body part affected is the trunk (16%) and the main injuries were wounds and cuts (34%). We can also see that accidents occur separately in the morning and in the afternoon, with a larger incidence in the morning (45%) and mainly in the viaducts and bridges (60%).

5 Conclusion

In this paper a case study on the implementation of the safety and health management system on construction sites was presented. It applies to all road constructions promoted by one of the largest owners of public work in Portugal – The Portuguese Road Institute (IEP).

The results achieved with the implementation of the System show that the working casualty rates decreased from 2001 to 2002, when the system was implemented, being the values about 30-40% lower than the previous year.

On the other hand, there is a clear tendency of decreasing in the number of days lost by accidents and in the seriousness of those accidents.

It can also be seen a decrease of about 50% of both fatal accidents and the relation between these and the total accidents.

IEP is encouraged by these results, as they indicate that the way followed leads to the success.

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Safety and Health Coordination in Portugal – Theory and Practice

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Abstract

The European Directive n.º 92/57/EEC concerning safety on temporary or mobile construction sites brought to the European countries new documents and agents related to the management of safety prevention in the construction industry. This Directive also establishes a chain of responsibilities linking all the parties involved in this process. During 1995 this European Directive became law in Portugal (Decree Law 155/95, 1st of July).

In Portugal, seven years after this law publication, there are still sites that do not follow the obligations concerning the elaboration of these documents and/or the appointment of the coordinators for safety and health matters.

This article will provide a general overview of the actual health and safety management situation, our experience as a consultant company and will try to present some aspects that may contribute to the improvement of the system.

Keywords

Safety and Health Coordination, Lines of Improvement, Portugal

1 Introduction

Although the European legislation was transposed into the internal legal system seven years ago, there are no clear evidences of its consequences by the reduction in the accidents rates as shown in the figure below.

There are however some good examples of stakeholders that take the initiative to implement good health and safety measures in their projects. At this point the major problem lies at the small projects level, that represent a very significant part of the Portuguese construction industry, namely in housing construction, refurbishment, maintenance where there is a lack of perception resulting in an inadequate application of the legislation.

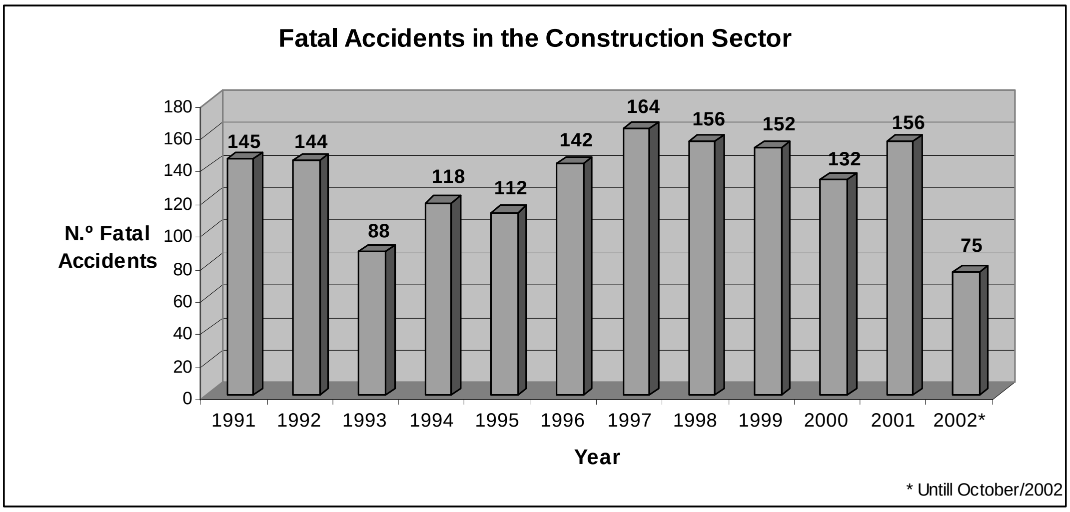

Figure 1 – Fatal Accidents in the Construction Sector [1]

2 Legislation

The "new" documents presented in the Decree-law 155/95, 1st of July, as it is well known, are Prior Notice, Health and Safety Plan and Health and Safety File. The Prior Notice has the purpose to inform the authorities of the opening of a new site. The Health and Safety Plan is the document where the major risks that may not be avoided during the design phase are described, along with preventive and protective measures proposed to reduce their impact. Finally, the Health and Safety File should contain the relevant safety and health information, related to the facilities, to be taken into account during any subsequent works (maintenance, refurbishment, demolition, etc.).

The two new agents referred in the Directive are the coordinator for safety and health matters at the project preparation stage and the coordinator for safety and health matters at the project execution stage.

In Portugal, seven years after the publication of this law, most ordinary sites do not follow the obligations concerning the elaboration of these documents and/or the appointment of the coordinators for safety and health matters. However the situation is different on what concerns big and complex projects where some owners have already concerns regarding safety.

The main reason for the poor acceptance of the legislation, besides the lack of promotional information by all construction intervenients, is probably within itself. Some contradictions and misunderstandings allowed the construction owners to make erroneous interpretations (namely appointing the coordinator directly when this should be done through a contractual agreement) and to avoid its application. It is also relevant that there is not yet a profile definition for the coordinator allowing the responsibilities to fall into the main contractor area after its appointment by the owner.

Due to that, in August 2002, a draft project of the Decree - Law 155/95 revision was made available for public discussion. This draft project comprises the following changes, with respect to the current version:

(a) It specifies the minimum content of the Health and Safety Plan and Health and Safety File;

(b) It indicates that the two agents (coordinator for safety and health matters at the project preparation stage and coordinator for safety and health matters at the project execution stage) must have specific professional skills / profile (however, the document does not mention which skills);

(c) It obliges the Public Construction Owners to include the Health and Safety Plan in the tender phase so that the contractors can be aware of their health and safety duties while preparing the bid (except if the design is made by the contractor);

(d) It stipulates that the coordinator for safety and health matters at the project execution stage can not be involved in the construction as contractor, subcontractor or self-employed worker;

(e) It requires the Owner to write a declaration identifying the coordination for safety and health at both project and execution stages, their goals and functions as well as the obligation of all parties to cooperate with both safety and health coordinators.

3 Major Factors Concerning the Current Situation

As mentioned before, there are still many sites that do not follow the obligations referred in the Directive and there are several problems that contribute to the current situation, namely the following:

(a) The Decree-Law concerning safety on temporary or mobile construction sites has some slips that lead to some contradictions and misunderstandings;

(b) The Decree-Law concerning safety on temporary or mobile construction sites, as well as its revision, indicate the Owner as the first responsible concerning health and safety matters. However, most Owners are not aware of this responsibility. During the tender phase, most Owners do not include the Health and Safety Plan (HSP) in the terms of reference, as they should; they require, instead, the tendering contractors and/or project manager to submit a HSP to the specific construction conditions;

(c) The law specifies that it is an Owner’s responsibility to appoint the coordinator for safety and health matters when it should be a contractual act/agreement;

(d) There is not yet a profile definition for the safety and health coordinator;

(e) Design Authors and Project supervisors at the design phase are not aware of their responsibilities and do not review their work regarding the safety aspects;

(f) The competent controlling entities have a punitive type of intervention rather than an educational one;

(g) The cost-benefit component of prevention is not considered during budgeting. The “prevention as merely a cost” view is a culture problem. The work accidents are analysed only by the direct costs involved;

(h) The safety culture is a concept that is not yet a practice in the construction sector. There is a need to increase employers pride to work in the construction sector so they can consider safety not as a priority (that can change due to external factors) but as an inner value.

4 Lines of Improvement

Firstly, we must point out as an important line of improvement the Decree-Law revision itself since it demonstrates a general concern towards continuous improvement.

There are also some initiatives that could be adopted by the competent entities in order to become lines of improvement, namely the promotion of appropriate instruction sessions to the private promoters and public developers in order to clarify and reinforce their legal obligations.

It should be encouraged within the professional association the promotion of awareness session including the legislation and the development of the Health and Safety Plan to small contractors.

Basic practical promotional information should be prepared and distributed to small contractor and general public as potential owners

Academia (universities) should be encouraged to carry out studies concerning safety implementation costs *versus* work accident costs in Portugal. It should be easier to really show the Owner with numbers that safety pays itself, if the study actually reaches this conclusion.

5 Our Experience

Our company has been related during the last years to an average of up to 20% share of the Portuguese public construction market especially taking care of site supervision and control aspects, with a relevant percentage in the most important public construction works that were carried in Portugal during the last years. Recently, a study was promoted within our company by the Quality and Safety Department to evaluate the main changes related to safety concerns in the public contracts we are involved in.

The study's main conclusion was that, from 1995 (when the Directive was transposed to internal law) until now, project characteristics that particularly refer safety concerns are changing. Initially, only the big projects (when we refer "big" it is according to the effective values of the award of Public Works tenders) used to include health and safety aspects in their tender documents. Nowadays the effective value of the award contracts that include health and safety aspects is decreasing, indicating that these concerns are getting known and more important to smaller Owners and smaller contracts.

In our company, for every contract we have, even if the Owner does not specify our intervention in the Health and Safety Coordination area, it is requested a meeting with the client to provide a small awareness session to the legislation and parties responsibilities (Figure 2 – Index of the Health and Safety Coordination Awareness Session).

From our experience, most Owners are surprised with the responsibilities attributed to them, thus showing their lack of information in these matters.

Figure 2 – Index of the Health and Safety Coordination Awareness Session

Our department also provides continuous information sessions for the company´s technical staff (site engineers and supervisors) highlighting the main aspects related to safety and health matters, mainly during the construction phase.

It is also one of our common practices, to provide sessions for the design authors and to promote the use of risk assessment sheets (Figure 3 – Example of a Risk Assessment Sheet) in order to systematically identify and register the risks and the respective preventive measures adopted during the design phase.

CONSULGAL	RISK ASSESSMENT SHEET		Number	Page.:
	Client: CIB		H&S Coord.: CONSULGAL S.A.	
	Project: EXAMPLE		Designer	

Design		
Facilities:	Design number	Rev.
Description	Phase	Date:
	1º. ☐ 2.º ☐ 3.º ☐	

Risk Identification
Activity:
Location
Risk:

Risk Assessment			
1 Low	2 Average	3 High	Probability / Danger
			1 Low
			2 Average
			3 High

Preventive Measures and Recommendations		
Preventive Measures to be adopted at the design phase	Risk Elimination?	
	Yes	No
Recommendations to be adopted during the construction phase (1) (2)		

(1) To include in the Health and Safety Plan.
(2) To include in the Health and Safety File.
CONSULGAL ◊ Mod. S21

Figure 3 – Example of a Risk Assessment Sheet

Our company was also committed to actively contribute to the decree-law revision while it was in the public discussion stage, thus stressing our worries and sharing our experience acquired in these areas over the years.

Last year, an electronic database was developed and successfully implemented in our company. It comprises important information to our company's activities including health and safety legislation, accidents rates in all our construction sites, some examples of good working practices and specialised magazine articles. It also allows our site teams to access our Safety Manual where they can obtain relevant information relating to preventive measures on several construction processes.

6 Conclusion

Firstly, the safety culture must continue to change in Portugal. In many cases those involved in the construction process are "encouraged" to implement health and safety measures according to the legislation and its penalties. The safety aspects should not be considered as a priority because priorities change. The safety culture should be considered as a value translating a personal belief.

For reaching such goal, the safety and health aspects should be an object of specific education programs as well as several training and promotional sessions.

Nowadays, the safety and health aspects are becoming more important in the owner's point of view, namely due to the legal penalties.

According to our experience, health and safety aspects are becoming more and more a common concern and, although we still have a long way to go, we can clearly point out some positive changes in the Portugal's reality.

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Economic analysis of safety risks in construction

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Abstract

The objective of this study revolves around the analysis of the safety risks involved with one construction project, and the respective economic effects of risk prevention and safety management. As a result of the co-ordination of systems, and harmonising of work between the Project Leader, Safety Co-ordinator and Contractor, an adequate strategy was developed for the safety of the project *Sheraton Porto Hotel*.

The *Sheraton Porto Hotel* project is situated in the centre of the city Porto. The area is destined to become a luxury hotel, containing underground car-park. The construction area covers around 45,000 m^2.

The management policy on Prevention, Hygiene and Safety is ensured by the following bodies with respective collaborations:

- General Safety Committee / Prevention and Safety Officer
- Co-ordination of on-site safety / General Safety Committee (from the point of view of Project Leader / Safety Co-ordinator).

The risk evaluation is carried out in simulated form, and task by task, introduced into the work programme. This gives a history of risk evaluation over the course of the project. The simulation allows peaks of risk to be identified, which will then lead to additional proposals of prevention measures. These prevention measures will serve to reduce risk and consequently lead to a curve on the risk chart. They consist not only of on-site measures, but also of the integrated implementation of working safety policies. We should be aware that risk can be reduced, but is difficult to eliminate altogether.

The implementation of prevention systems and working safety policies has its own cost, but what we intend to prove, by attributing costs to risks, is that safety has lower costs than a lack of safety.

Keywords

Safety; construction; risk evaluation.

1 Introduction

The Safety and Health Coordination Staff of the Sheraton Porto Hotel Project, Porto, Portugal, in collaboration with the Civil Engineering Department of Minho University, has decided to make an economic study of risks, through its study during the work. This programme will be based on the detailed working programme, now approved.

The project programme required the foundations started on August 2000, and project completion by the March 2003, approximately two years and a half, in duration.

To each of the working programme activity is associated a risk evaluation dossier by the Safety Coordination, containing not only risks, but also preventive measures.

The evaluation of risks and choice between a preventive or non-preventive attitude leads to two different situations: the performance or inexistence of security during the work. This way, at the end we have two final risk histograms.

Figure 1 – Panoramic view of Sheraton Porto Hotel

2 Experimental

Having a detailed working programme of Sheraton Porto Hotel Work as a basis, a study of total risks associated to the different activities concerned, has been done. Two simulations have been taken into consideration: one concerning the maximum risk evaluation, stressed by the inexistence of preventive measures on the works; the other fulfilling all possible preventive measures, however without eliminating all risks, as there will always be risks even if minimal.

The risk associated to the activities working programme of the correspondent work, with more than 1000 activities, is analysed in each of the activities after considering the information included in the Safety and Health Plan, in force in the work. The Safety and Health Plan contains Inspection and Prevention Procedures adaptable to the activities, related to the risks of each activity, as well as the preventive measures that can be implemented in the work, in order to minimise the correspondent risks.

So, it has been elaborated an inspection and prevention procedures table for each activity.

To optimise the use of that data, the procedures became part of the working programme activities.

For each Inspection and Prevention Procedure, i.e., for each activity, there are various risks associated. In the shipyard referred to this study, 82 types of risk were detected, with varying frequency. According to the computer program used, these risks are included in the resources of different activities.

In order to evaluate risks, an evaluation table was evolved, witch considers the severity and possibility of occurrence. The risk scale ranges from 1 to 5, taking into account that there is no 0 value risk, as there is always risk, even if minimal.

Taking into consideration the lack of prevention at the work, a maximum value for each risk has been defined, as in some cases it reached 5, for instance falls from height. Risk 1 was defined considering the full use of prevention, whichever the circumstance, as this is, as previously referred, the minimum risk value assumed.

After considering all those elements, the experimental phase follows, and it is time to insert in the "Primavera Project Planner", a project management computer program, all connected activities, as in the approved working plan, and all activities related to risks, as if it was an activity resource.

After that treatment, the simulation values of risk to both situations that will be simulated is added. One corresponds to total inexistence of prevention and the other to full prevention measures, and a study of both risk situations is done, having the histogram of the work plan related to working programme, as its basis.

3 Results

According to the data inserted in the program, results are simulated for both situations. In the first situation, where risk analysis is maximised, taking into consideration the fact that there is no prevention, there is a total result of 356.663 risk points, adding all risks related to the activities. In the second situation, assuming that there is full prevention of risks at all levels, the total of risk point is 92.354.

It should be noted that when prevention is not implemented the risk is 4 times greater than prevention is fully implemented.

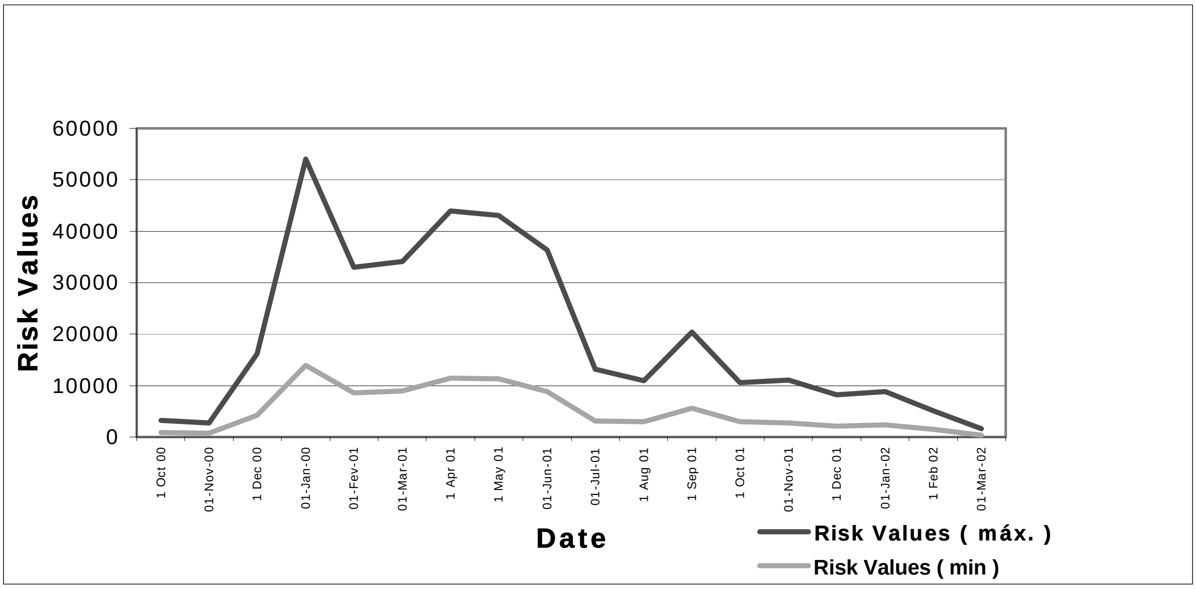

Figure 2 – Sheraton Porto Hotel – Risk Values Monthly

4 Discussion

Taking into consideration the 3.86 as the maximum average reference point, during the work, it is quickly noticed that in different phases, the difference of risk occurrence highly surpasses these values and so, apart from normal prevention situations, it is extremely important to act in "peak" risks. A parallel analysis can also be done, so as to evaluate the risks and costs, and to know "how much it costs to create safety".

Taking into consideration recent studies that show that safety costs for a similar work in Portugal rarely surpass 2%, it is possible to say that this percentage corresponds to the maximisation of risk prevention measures implemented in the work. This study shows that risk maximisation without prevention is 3.86 times larger, which also means that costs of safety can reach 7.72% of costs, i.e., 5.72% more than the costs of implementing safety measures.

Application of these values to the Sheraton Porto Hotel, with a project value of 15 millions of Euros, results in the following costs:

- Costs of implementation of prevention measures
(2,00%) ~ 0.30 millions Euros

- Potential costs of non-safety
(7.72%) ~ 1.16 millions Euros
- Potential risk of added costs due to the non-existence of prevention
(5.72%) ~ 0,86 million Euros

It is important to remember that the cost of non-safety are both quantifiable (fines, employees' salaries, lawyers, spoiled material, etc) and unquantifiable (work interruption, reduced of productivity, boarder of directors´ time marginalised, company image, prestige, etc) the latter ones are no included in this study.

5 Conclusion

This study applied to the Sheraton Porto Hotel project, in Porto, Portugal, indicates that it is beneficial to invest in prevention. Apart from the need to minimise task risks, through the inclusion of safety measures in the Inspection and Prevention Procedures for tasks, there are other measures which can be implemented to realise even more benefits:

- Coordination Meetings with all contributors.
- Safety Working Commission Meetings.
- Training, counselling, and informing of all workers and managers.
- Discussing of the Safety and Health Plan with all participants from all working sectors, throughout the project.
- Planning all activities in order to assure the implementation of safety measures in future work.

All these measures are solutions that approximate safety costs from values practised, by those that care about prevention, and risk minimisation.

It is, therefore, logical to state the aphorism "Decreasing risks means decreasing work costs".

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Improving Safety Performance on Large Construction Sites

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Abstract

A recent safety study conducted on large construction sites, valued between $50 million and $600 million, in North America revealed that construction safety performance is influenced by a number of factors. It is clear from the research results there is no single safety practice that can be implemented to ensure that safety performance is optimal. Instead, a concerted effort is required in which several different practices must be implemented. Factors that are influential in impacting safety performance include demonstrated management commitment, project safety staffing, safety planning, training and education, worker involvement, rewards and recognition, subcontractor management, drug testing, and accident investigations. The research disclosed that there are various ways of addressing these practices. It is also evident that the construction industry is maturing and is aggressively seeking new and innovative ways to establish safety as a primary objective. In a study of 38 large construction projects, four had achieved an Occupational Safety and Health Administration (OSHA) recordable injury rate of zero.

Keywords

Best practices, jobsite safety, safety programs

1. Introduction

The safety performance of the construction industry has consistently been below that of most other industries. Despite this, the construction industry has made considerable improvements in safety performance in the past two decades. Statistical data provide documented proof that improvements have indeed been made in the safety performance of the construction industry. For example, the OSHA recordable injury rate in 1990 in the United States was 14.2 and in 2000 it had dropped to 7.71. What is not clear is how these improvements were actually achieved. Many different safety practices have been devised, adopted and implemented in recent years, but it is not clear which particular practices are responsible for these improvements. Are certain practices particularly effective in impacting safety performance or do they all contribute to improved performance?

Safety improvements are particularly evident on large construction projects. While safety performance may be good on some small projects, it is on large construction projects that safety performance is consistently quite good. The safety performance records on large projects are also generally quite reliable as a large number of worker hours are expended on a single project. Since most firms involved in large projects are willing to provide the results of their safety efforts, a great deal can be learned by studying the safety practices implemented on large projects. These can then be considered for implementation on other construction projects.

2. Background

A number of safety studies have been conducted to identify effective safety practices in large construction firms. In a 1981 study of the 100 largest construction firms in the U.S., safety practices were identified that were associated with better safety performances. Firms with better safety records were those with full-time safety officers with considerable authority and when full-time safety officers were assigned to most company projects. These safety officers hired their own subordinates and they reported directly to the company president or vice president. Additionally, it was found that safety performances were better when all new workers received formal orientation. It was also found that safety performances were better in those firms providing safety incentive awards for their workers and foremen (Hinze and Harrison 1981).

In a Construction Industry Institute study on high-rise construction projects in Canada, additional factors were identified that influenced safety performance. The findings showed that safety performances on projects were better when full-time safety officers were assigned to projects and when top management actively and visibly participated in the safety program. Better safety performances were also noted on projects where individual records were kept on the safety performances of the foremen, where jobsite safety inspections were conducted on a regular basis, and where safety was discussed in the regularly held coordination meetings. It was observed that better safety performances occurred on projects that were either under budget or on budget and better performances also existed when contracts were negotiated instead of being competitively bid (Hinze and Raboud 1988).

A report released by the Construction Industry Institute (1993) identified five high impact techniques for achieving zero accidents. These included pretask/preproject planning, safety orientation and training, safety incentive programs, alcohol and substance abuse programs, and accident/incident investigations.

In another study of a survey of the top 400 contractors, several practices were identified as favorably influencing safety performance (Eich 1996). For example, better safety performances were reported by those firms that gave incentive awards for safe crew performance (as opposed to safe individual performance), that imposed sanctions for unsafe behavior, that provided formal orientation training to all new employees, that held periodic safety dinners, and that implemented drug testing programs.

One recent study showed that representatives of large construction firms tended to agree with the findings of the zero accidents study. They also stated that they had made changes since the zero accidents results were publicized (Hinze and Wilson 1998). It was evident that changes had taken place in the construction industry, but that there was no clear evidence as to their effectiveness.

3. Research Methodology

With the changes that had taken place in construction safety practices, a proposal was submitted to the Construction Industry Institute to study factors that impact safety performance on large projects. This proposal was funded and resulted in the research that is reported here.

The object of this research was to identify those contractor practices on large construction projects that are particularly effective in favorably impacting safety performance. The projects to be included in this study were large construction sites, those valued from $50 million to $600 million. All known projects that satisfied the size criteria were contacted and asked to participate in the study. All identified projects that met the size criterion were included in the study sample.

The research consisted of conducting personal interviews with a contractor representative who was resident on the construction project. On most projects this was the safety representative but in some instances it was the project manager. The ten-page questionnaire addressed many safety issues including jobsite characteristics, owner involvement in project safety, safety staffing, safety planning, training and education, safety meetings, incentives, safety audits, drug testing, subcontract management, accident investigations, insurance company involvement in the safety process, inclusion of OSHA in the safety process, and safety performance information. Interviews were generally conducted in one to two hours. In a few instances, interviews were conducted over the telephone. In total, 38 interviews were conducted.

4. Data Analysis

The data analysis identified the safety performances associated with differing types of practices being implemented on construction sites. Of particular interest in this research were findings that identified those practices that were particularly effective in enhancing safety performance. Effectiveness was measured in terms of the OSHA (Occupational Safety and Health Administration) recordable injury rate that equated to the number of OSHA recordable injuries incurred per 200,000 worker hours of exposure. For this study, the median OSHA recordable injury rate was 2.0 injuries per 200,000 hours. It should be noted that the average OSHA recordable injury rate for the construction industry for this same period was nearly eight, so it should be evident that the large projects generally experienced good safety performance.

In this research, four of the large projects reported OSHA recordable injury rates of zero and 21 reported lost workday injury rates of zero. Although the projects included in this research generally experienced good safety performance records, the analysis focused on identifying those policies and practices that were associated with particularly good injury rates. The findings of particular interest were those policies and practices that were found to show a statistically significant correlation (using Kendal's correlation) with the OSHA recordable injury rate. Findings were considered to be statistically significant if the level of significance was less than 0.05 and a tendency towards was assumed to exist if the level of significance was between 0.05 and 0.10. For the findings presented, it should be noted that some interview participants were not responsive to some questions.

5. Research Results

5.1 Demonstrated Management Commitment

No reasonable manager would admit to having no regard for the safety of workers. Safety is fundamental and it is generally regarded as being a goal worth achieving. The key to success lies in the demonstration of that commitment to safety. There are of course many ways that this can be achieved and done. In the end, it is not what management says, but what it does. For example, the research showed that safety performances were better when top managers were involved in more frequent jobsite safety inspections (see Table 1).

Table 1: How often does someone from the home office make safety inspections?

Response	Number	Median Injury Rate
Weekly, bi-weekly, or monthly	24	1.38
Quarterly	14	2.57

Correlation Coefficient = 0.24 Level of Significance = 0.03

5.2 Safety Staffing

On large construction projects, most with hundreds of field workers employed, it is not possible for the safety needs of the workers to be adequately addressed by the site supervisors. The site supervisors need additional assistance and this is where safety personnel can be particularly helpful. Safety personnel can serve as a safety resource that can make a significant difference. But how many safety personnel are needed to adequately address the needs of the site supervisors? The unique site conditions will dictate the answer to some extent. Certainly, the safety personnel must be viewed as resources that are at the disposal of the site supervisors to promote the safety mission. The research showed that better safety performances were realized when the ratio of workers to safety personnel was small (see Table 2). In addition, it was found that better safety performances existed on projects where the project safety director reported directly to someone in the home office, rather that have reporting responsibilities to someone in line management at the project level. The safety director’s focus can clearly remain focused on safety issues when the reporting is to someone who is not directly affiliated with the project (see Table 3).

Table 2: Number of workers per safety person.

Workers per Safety Person	Number of Projects	Median Injury Rate
1 to 20	3	1.11
45 to 70	3	2.81
100 to 150	8	2.92
181	1	5.1
500	1	8.04

Correlation is not statistically significant (Note: several projects did not provide these data)

Table 3: To whom does the safety representative report?

Response	Number	Median Injury Rate
Staff (Main Office/ Safety Director)	19	1.38
Line (Project Manager)	16	2.41

Correlation Coefficient = 0.20   Level of Significance = 0.07

5.3 Safety Planning

Safety planning is vital to project safety. There are two types of safety planning. One consists of pre-project planning and the other consists of pre-task planning. Note that pre-project safety planning and pre-task safety planning are synonymous with pre-project planning and pre-task planning, respectively. When planning is done, whether at the project or task level, it is important that safety be addressed along with the other aspects of performing the work, as safety cannot be addressed as a distinct and separate issue. Safety simply must be integrated into the planning process. One means of integrating safety into the project is by preparing a site-specific safety program. Through a site specific safety program the contractor identifies all major job hazards and devises means of addressing them to maintain a safe project. These are commonly employed on large projects, and they have been shown to favorably impact jobsite safety (see Table 4).

Table 4: Is there a site-specific safety program for the project?

Response	Number	Median Injury Rate
Yes	34	1.76
No	4	5.43

Correlation Coefficient = 0.20   Level of Significance = 0.08

5.4 Safety Training and Education

Worker training, especially worker orientation training, has been recognized as vital to achieving good safety performance. As a result, it is common on large construction sites for orientation to be offered. The issue that is important to worker safety is that the orientation must be provided to all workers and it must be formalized (standardized to ensure that every worker receives the same quality of orientation training). As in past construction safety research, new worker orientation continues to be of vital importance to safety (see Table 5). Findings show that training must continue beyond the orientation training, and this training must be provided to both workers and supervisory personnel (see Table 6). Safety training also appears to be most effective, as evidenced by lower injury rates, when there is some means of measuring the effectiveness of the training.

Table 5: Does every worker on the project receive orientation training?

Response	Number	Median Injury Rate
Yes	30	1.76
No	8	5.72

Correlation Coefficient = 0.24   Level of Significance = 0.05

Table 6: How much additional training do workers receive each month?

Response	Number	Median Injury Rate
Less than 4 hours	10	3.76
More than 4 hours	17	1.07

Correlation Coefficient = -.35 Level of Significance = 0.01

5.5 Worker Involvement

One of the newest innovations in the area of safety in the construction industry is the increased involvement of workers in the safety process. Workers should be viewed as a resource for ideas. The adage that "two heads are better than one" certainly applies here. If a foreman has five workers in the crew, that supervisor has ready access to the experiences and perspectives of five different individuals that can each contribute in a unique way. Not only will the ideas being generated be richer, but there will also be an increase in worker satisfaction. There are various ways that worker ideas can be tapped. Better safety performances were noted to occur on projects that organized safety committees (see Table 7), that conducted formal worker observations, also referred to as behavior-based safety (see Table 8), and where worker safety perception surveys were conducted (see Table 9). Suggestion box programs and pre-task planning were also conducted. Others may also be employed, depending on the ingenuity of the supervisor and project team.

Table 7: Does your project have a formal safety committee?

Response	Number	Median Injury Rate
Yes	26	1.76
No	11	2.82

Correlation Coefficient = 0.22 Level of Significance = 0.07

Table 8: Does the project have a formal behavior-based program?

Response	Number	Median Injury Rate
Yes	23	1.38
No	15	2.82

Correlation Coefficient = 0.29 Level of Significance = 0.02

Table 9: Does the company use safety perception surveys on the project?

Response	Number	Median Injury Rate
Yes	19	1.33
No	19	2.82

Correlation Coefficient = 0.30 Level of Significance = 0.02

5.6 Rewards/Recognition

Among the different approaches that have been employed to improve jobsite safety, safety incentives are among those that have been explored for decades. Incentives are designed to be a form of positive reinforcement. That is, an incentive is given to workers who meet certain safety performance criteria. Where safety incentives are concerned, the incentive is generally given to workers or crews that do no have an OSHA recordable injury in a stipulated period of time. In this research, only four construction projects were identified that did not employ safety incentives. It was interesting to note that these four projects actually reported lower injury rates than the projects that employed. While most projects did employ safety incentives, it is also clear that good safety performances can be attained without them.

Incentives are ideally a physical or visible demonstration of the commitment of the company to safety. The data were examined to determine is there were any unique techniques of using incentives that were more effective. For example, it was noted that among the projects that utilized safety incentives, better safety performances were reported when the incentives were given more frequently (see Table 10). Of course the traditional incentives are also criticized as being related to a negative measure of safety performance, worker injuries. The incentives are lost when an injury occurs. Many favor more pro-active approaches to safety in which the safe behavior of workers is rewarded. It has been argued that a worker may work in an unsafe manner, receive no injuries as the work is performed, and ultimately be rewarded for the efforts, despite the fact that the work was not performed safely. Basing incentives on safe behavior, rather than on injury occurrence, is more directly focused on the intent of promoting safe work. This type of program is more difficult to implement and maintain, but such programs have been shown to be very effective. Under this type of program, a worker who is observed as performing a task in a particularly safe manner is provided with an "on-the-spot" reward or token (for example, a sticker posted on the hard hat.). These tokens can be accumulated and later redeemed through a catalogue in which gifts of differing values can be obtained. While positive reinforcement has its obvious impacts on safety performance, it was found that better safety performances were also noted when sanctions (negative reinforcement) were imposed when workers failed to work safely (see Table 11, the question says subcontractors, is it the same as workers?).

Table 10: How often are safety incentives given to workers?

Response	Number	Median Injury Rate
Weekly, Biweekly, or Monthly	14	1.33
Quarterly	7	3.29

Correlation Coefficient = -0.01 Level of Significance = 0.01

Table 11: Are sanctions in place for sub-contractors who violate safety procedures?

Response	Number	Median Injury Rate
Yes	28	1.45
No	4	5.41

Correlation Coefficient = 0.27 Level of Significance = 0.04

5.7 Subcontractor Management

Subcontractors play an important role in construction, i.e.; subcontractors perform most of the construction work actually performed. Consequently, it is imperative that the safety practices on a project fully include the subcontractors' workers or a double standard will be established. A double standard on safety can compromise the effectiveness of the safety program. It is important that all parties on the construction site follow the same safety procedures. Perhaps the most effective way to ensure that subcontractors will be safe is to conduct a thorough screening of the subcontractors before awarding the subcontracts (see Table 12). Once selected, subcontractors should be integrated into the overall project safety program. In addition, it is important that the subcontractors prepare and submit site-specific safety plans. This will ensure that they have thoroughly examined their scope of work and can perform it safely (see Table 13).

Table 12: Are subcontractors pre-qualified before consideration for the project?

Response	Number	Median Injury Rate
Yes	31	1.38
No	6	4.72

Correlation Coefficient = 0.28 Level of Significance = 0.03

Table 13: Are subcontractors required to submit site-specific safety plans?

Response	Number	Median Injury Rate
Yes	27	1.38
No	5	3.84

Correlation Coefficient = 0.25 Level of Significance = 0.05

5.8 Drug Testing

Drug testing is a common practice on many construction projects. There are several different types of drug tests. These include pre-employment screening, post accident, random, and for cause testing. Drug testing is vital on construction projects to ensure that the workers on site are competent. Since the late 1980s and the early 1990s, drug-testing programs have become commonplace on most large construction sites (Gerber and Yacoubian 2001). There are differences in the manner in which some of these programs are implemented. Most projects conduct pre-employment drug screening tests, but fewer projects conduct random drug tests. The research findings show that projects implementing random drug tests had better safety performances (see Table 14). It was also found when these tests are conducted that projects have higher injury frequency rates when the percentage of positive tests is high.

Table 14: Are Random Drug Tests Conducted?

Response	Number	Median Injury Rate
Yes	22	1.38
No	14	2.57

Correlation Coefficient = 0.21 Level of Significance = 0.07

5.9 Accident Investigations

Whenever an injury occurs, a message is communicated that something is wrong in the system. Injuries should not occur when everything takes place as planned. When a worker is injured, the initial and most important issue is that of obtaining prompt treatment for the injured worker. Once the injured worker has been attended to, attention will begin to focus on ensuring that a similar injury does not occur in the future. To do this, it will be important to understand the specific cause of the injury. This information can be obtained through a thorough investigation of the accident.

Accident investigations are important to identify the root causes of injuries. Once the root causes are identified, it is possible to begin to address the means by which such conditions can be avoided when similar tasks are performed in the future. Even if conditions cannot be entirely eliminated, it will be beneficial to simply be able to recognize the hazards harbored by given conditions. The research findings showed that the level of top management involvement in injury investigations also made a difference. Safer performances were reported when top management was involved in the investigation of every worker injury (see Table 15).

Table 15: Percent of OSHA recordable injuries investigated by top management

Response	Number	Median Injury Rate
100% (all)	14	1.20
Less than 50% (none were from 51-99%)	10	6.89

Correlation Coefficient = 0.55 Level of Significance = 0.01

It is a common practice on large construction projects to investigate all accidents involving lost workday injuries and OSHA recordable injuries. An even better practice is to also investigate near miss accidents. Near miss accidents are incidents that do not result in injuries but which might have, had circumstances been slightly different. Near misses are like "wake up calls" that do not result in injuries. When near misses occur, management should seize the opportunity to investigate the root causes so that similar circumstances do not arise in which a future injury might occur. Firms that investigated more near misses reported safer performances.

5.10 Additional Analysis

There is much speculation about the particular policies or practices that are most effective at reducing construction worker injuries on large construction projects. The answer to this question was sought through regression analysis; unfortunately, the sample was too small to conduct an effective analysis. Instead, another approach was used to examine the data. Rather than examine the impact of a single practice on the safety performance on the project, the cumulative impact of implementing a group of practices was examined. The results showed that projects that implemented more safety practices (at least 90 percent of the best practices identified) had significantly better safety performances with injury frequency rates of 0.18. Similarly those projects that did not implement many of the safety practices (no more than 40 percent) reported high injury rates averaging 7.61. Clearly, there is no single practice that can be implemented that can ensure the safety performance on the project, i.e., a concerted effort is required that involves the implementation of several safety practices.

6. Summary

The research shows that the safety performances experienced on large construction projects have improved considerably in recent years, noticeably better than the construction industry in general. It is also clear that the safety practices being implemented have changed in recent years to further enhance safety performance. The subject areas in which safety performance was found to be noticeably impacted by the implementation of specific practices include the following:

1. Demonstrated management commitment
2. Safety staffing
3. Safety planning
4. Orientation and training
5. Worker involvement
6. Rewards and incentives

7. Subcontract management
8. Drug testing
9. Accident investigations

7. Conclusions

Safety performance on large construction projects is influenced by the implementation of a variety of safety practices. The construction industry has matured in recent years and the safety practices that have been implemented have helped show the industry that further improvements can be realized in safety performance. A few projects have achieved the zero injury objective and this phenomenon can be expected to increase on more projects in the future. It is noteworthy that there is no single practice that accounts for all the advances in safety performance. The collective impact of implementing several safety practices does indeed make a significant impact on safety performance.

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Use of building product models and reference data libraries for project and quality management

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Abstract

Product model based design opens new ways of running building and construction projects. The IFC- and ISO12006-3 standard together encourages sharing and reuse of data throughout the whole building process. The IFC standard is already adopted in the software industry. Now it is time to adopt the standard and the new way of working, in the construction process as well. This paper will discuss the challenges and potential benefits of using building models and reference data for building and construction projects.

Keywords

Building model, data reference library, IFC, information exchange, interoperability, taxonomy

1 Definitions

Application	In the context of this paper application is used for software applications or computer programs.
Concept	A generic expression for any object, property, activity, unit or relationship
Objects	Used as a common description of subjects, properties, activities, units and values in the context of a data reference library.

2 Background

During the last 50 years we have experienced increased use of classification tables for the structuring of information. Traditional classification systems and standards have been proven difficult to implement in software, because they where originally designed for paper-type applications. Most of the systems are made for a particular purpose and are therefore difficult to extend to a larger scope. Information handed over from one phase of a building project to the next, will in most cases need to be retyped. On average, each piece of information will be retyped seven times throughout the whole building process [Bakkmoen].

To address this cumbersome process, many organisations have initiated projects to improve the exchange and reuse of information. Several ISO committees as ISO/TC59 Building and Construction, ISO/TC 10/SC 8 Construction Documentation and ISO/TC 184/SC 4 STEP- Standards for The Exchange of Product Model Data, are involved. In the oil and gas industry, EPISTLE has developed ISO 15926 as a core model for reference data libraries [Epistle].

2.1 The IFC standard

International Alliance for Interoperability [IAI/IFC] is an international organisation with a vision to improve communication, productivity, delivery time, cost, and quality throughout the whole life cycle of a building. IAI is responsible for the development of the IFC standard. IFC stands for Industry Foundation Classes and is a complete building product model and a standard for information exchange. The IFC standard is now implemented in most of the leading CAD software [IFC Impl.] When using the IFC standard for information exchange, one exchanges drawings as rooms, doors, walls and windows and not as lines and layers as in the case for de facto standards as DWG and DXF. This change offers multiple new ways of reusing information in the building process.

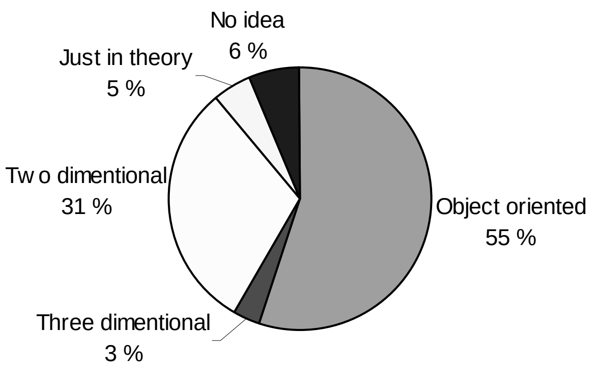


Figure 1: "How are you using CAD software ?"

An internet questionnaire study by ARCHmatic.com in Germany in November 2001 gave the following results on the matter; "*How are you using your CAD software*?" There were a total of 1015 answers. On the question "*Are you using IFC for data exchange*?", 49,9% answered "not to this date", 10,6% "a few times" and 9,6% "often" Only 8% were unaware of the IFC format.

2.2 The ISO 12006-3 "Framework for object oriented information exchange"

The ISO 12006-3 is an EXPRESS model giving a framework for reference data libraries. The framework is similar to the EPISTLE [ISO15926] framework, but only covers types of objects and is significantly simpler to implement.

ISO 12006-3 is a framework for computer sensible dictionaries. It allows for objects to have multiple descriptions and names in multiple languages. An object can be anything logical or physical. Activities, properties, units, measures and actors are also considered to be objects in the ISO 12006-3 context. Every object will have its own unique identifier that will be the same in different languages. This means that an object will have one; and only one identifier.

The ISO/PAS is not a framework for building products or building projects like the IFC standard. Nor is it a standard for information exchange. Libraries based on ISO 12006-3 will only consist of generic objects. A generic object is an object described independent of use and context.

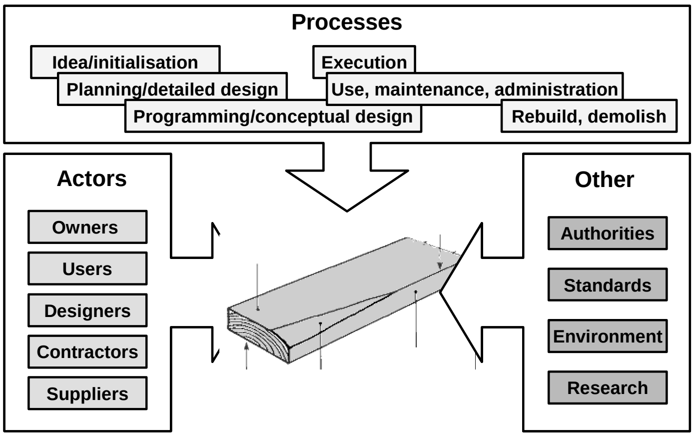


Figure 2: "Factors that influences information need"

The total amount of properties needed to describe even the simplest object is considerable when looking at the whole lifecycle of the object. Every actor will either give or require information about difference aspects of an object in different phases of the objects lifecycle. Authorities, classification systems and standards give additional demands for information.

A generic object has all the properties attached and can therefore be used as a "template" to describe the object in different contexts. As an example, the object "door" can function as a template to describe the door as a building product, as part of the construction process, as an object for maintenance or as a part of a fire escape system. Generic objects can be presented in different ways by means of templates. The use of templates is a technique to filter information needed for particular purposes or for particular users.

2.3 National reference data libraries

Today there are several ongoing projects using the framework of ISO12006-3 for national reference data libraries. The first two initiatives were the Norwegian BARBi [Barbi] project and the Dutch LexiCon [Lexicon]. Others are following, and there are now projects in England, France, and Australia. There is also an initiative to establish an international organisation to harmonise the different national libraries. The international organisation will assure that a concept will carry the same unique identifier in different languages, and establish a set of rules and guidelines on how to populate and maintain libraries.

2.4 The XM-7 Harmonization of ISO 12006 Part 3 with the IFC standard

While the IFC standard covers much of the information needed to specify objects in the building process, some information still needs to be defined within the scope of an application. For this IFC provides "IFC property sets". An IFC property-set is a mechanism to attach predefined and self defined properties to any of the core objects in the standard. This mechanism ensures the exchange of properties between applications but does not guarantee that the properties are understood in the receiving application.

The IFC standard defines objects down to a level of detail that can be agreed upon internationally. This means that you will find all typical construction applications, but not construction that is applicable for only one or a few countries. For country specific solutions you will need to store the information in self defined property-sets. The libraries based upon the framework of ISO 12006-3 can, on the other hand, standardise any object or construction down to any level of detail. This is why the harmonisation of these two standards has got a high priority both from the IAI and from the ICIS [ICIS] community. Integration of the two standards gives the mechanism that allows standardisation of all the information in a building project.

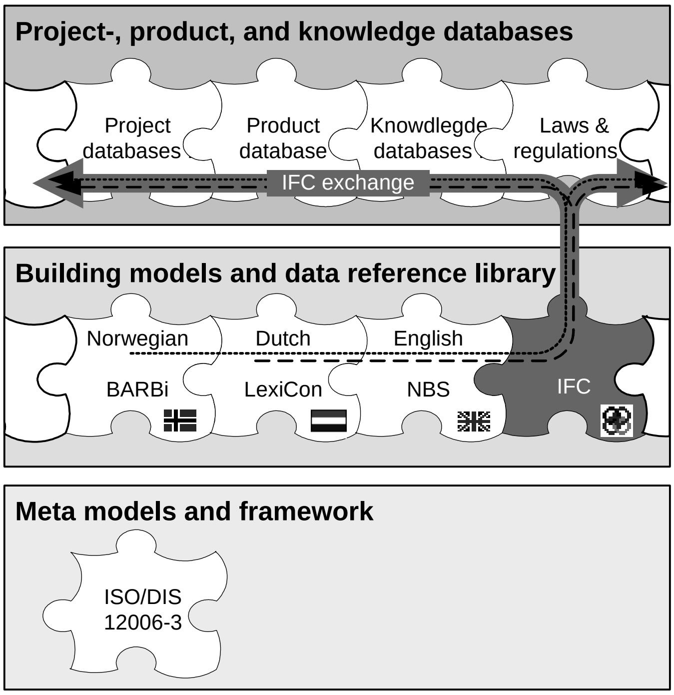


Figure 3: "integration of ISO 12006-3 and IFC"

The Norwegian BARBi project tests the integration of IFC and ISO 12006-3 reference data by mapping the IFC to the content of the BARBi library. This provides a link between the generic national object names and definitions, and the IFC objects and properties. This allows not only for automatic translation of objects between national standards and IFC but also for exchange of reference data in IFC format. The result of the mapping will hopefully begin a standardisation of all exchanged data. Results of the test project will be published in a later report.

Figure 3 shows the three different layers of abstraction of information. The bottom layer is the core framework with basic concepts like subjects, activities, actors, units, and properties. The middle layer includes generic reference data libraries and building product models like IFC, while the top layer consists of instances of objects like a product in a product catalogue, a door in a building, or a "best practise" in a knowledge database.

2.5 Limitations of de facto standards

Management of projects is very much a matter of management of information. The lack of a common standard for in example CAD information has lead to a wide use of de facto standards. The DWG standard is for example much used for storage and exchange of drawn data. Such standards change frequently with new versions of the corresponding software, and they often have poor backwards compatibility. The fact that the standard is owned by a particular company disfavours other software. As a result a project manager might choose to standardise on software rather than on file format, enforcing architects and engineers to use software they might not be familiar with.

De facto standards are built to serve the software they are designed for and have often a limited scope. The DWG standards works well for drawn information but does not serve other purposes like time schedules and cost calculations. In the same way will file standards used by project planning applications work for CAD applications. In a typical building project information is spread over a wide range of file formats each fulfilling a particular purpose. Information that could and should be shared among applications is fed into each system separately, and much effort is put into repeating information that is already present in other applications. [Bakkmoen]

3 Product model based design

The information flow in building projects is typically fragmented and human reinterpreted. What we want is a model-based design where all information is structured around a product-model of the information. We want to share standardised data.

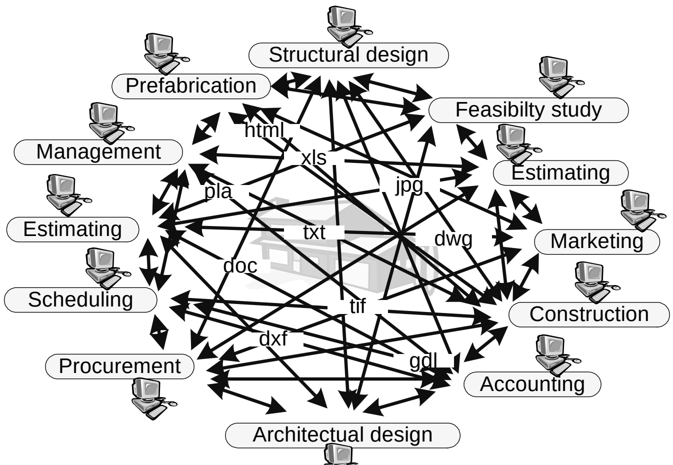
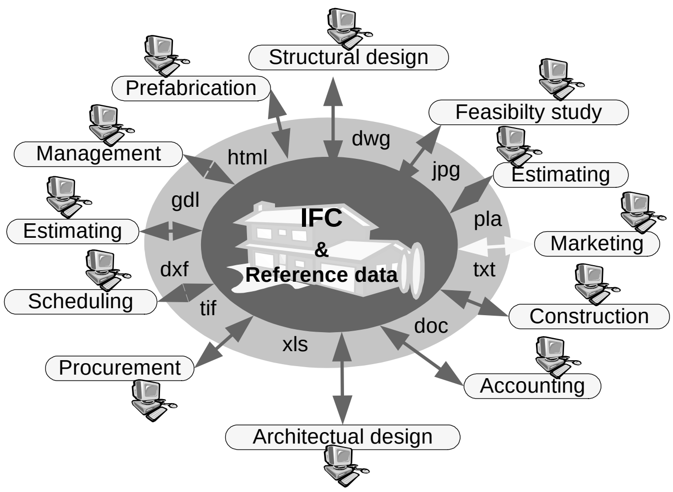


Figure 4: "today's fragmented information flows"

In a typical building project, information is sent to different people using different methods of information exchange. Most information is unstructured or semi structured [Froese]. The information exchange is a mixture of phone calls, e-mails, faxes, letters or drawings. The resulting documentation of the project is fragmented and stored in different formats. Information from early phases is rarely updated with the changes done later.

When information is handed over from one phase to another it will in most cases have to be manually read and reinterpreted before it is used in software for later phases. Apart from the extra work involved such workflow also includes a great risk of errors and loss of data.



In a product model based design, all information is structured around a product model of the information. The IFC standard can carry information about the products, parts and the functions of a building as well as non-product information such as cost, schedule, resources, documents, classifications, organisations, etc. A benefit of using model-based design is the sharing and reuse of

Figure 5: "product model bases design"

data. Information added from one application can be reused by other applications without the need of retyping information.

In an IFC based product model, design information is stored on a model of the building project itself. All information regarding the graphical design, materials, schedules, actors, costs, quantities and specifications is stored in the same product model. The strength of the IFC standard was clearly demonstrated at the IAI Summit 2002 seminar in Helsinki, Finland in April [IAI Summit]. Many companies and projects had used the IFC standard for project management and information exchange with good results.

Companies were using IFC data as a basis for decision-making in the early phases of the building project. [IAI Summit] On a 3D drawing from the architect they could run energy simulations, sound and comfort simulations, life cycle and lightning simulations.

Meetings where held in the virtual building prior to construction. The people involved could walk inside the model of the building discussing solutions [Eve]. By using colour schemes on the 3D model they simulated the flow of air from ventilation systems and heat loss through parts of the construction project. Changes to the design could be done directly at the meeting using standard CAD applications.

The Singaporean building authorities are using the IFC model as a basis for automated control towards national building regulations [Cornet]. Architects and engineers can upload their building models on a server and run queries on the content to control their drawings. The result is visualized in an Internet based browser where construction parts that did not pass the test were coloured and linked to a report with the explanation for the failure. When the building is cleared it can be submitted for manual processing.

Product model servers based upon IFC enables a new way of editing objects throughout the process. Instead of sending a huge amount of data every time a part of a drawing is changed, it is now possible to change only the object or objects affected. In an IFC model-server each actor in the process have a role, which gives the user the right to read, update, delete or change objects. With this technology it is possible to track the total history of each object in the lifetime of the project, while still having manageable amounts of data. Actors can lock objects to prevent others from changing the same object while they are working on it. [IAI summit]

Product model design can be regarded as a simulation of the construction process. Construction, demolition, logistic and maintaining processes can be simulated on the building prior to any construction on the site. Cost estimates can be simulated in time and different scenarios can be analyzed. Procurement procedures can be linked to the 4D model and automated bills of quantities produced. The same model can work as a basis for simulation of facilities management (FM) scenarios for rental, sale or maintenance [IAI Summit]. For project managers this allows to explore the implications of different scenarios in more detail. The time it takes to gather the necessary data to decide whether a certain scenario is realized is reduced. Decisions regarding the building or the rebuilding process involve large amounts of money. By applying IFC models these decisions will be based on more solid information and the risk of making the wrong decision is reduced.

One of the key benefits of working product model design is the reuse of information. If a rich product-model is produced early in the project, it will benefit actors in later phases. HVAC engineers can reuse structural- and room information to calculate the need of ventilation and heating. A civil engineer can work with parts of the facility, reusing material information and feeding back information about such information as reinforcement, load bearing and material qualities. Contractors can automatically generate formwork drawings from the product model because the information about what the walls and slabs are made of is already stored in the model. Orders of building products and materials can be automatically derived from the drawing, and the choice of products can be fed back to the product model. Facility Management and real estate people can read and extract information that is relevant for them like room information, functions, surfaces, guaranties and maintenance data for products. [IAI Summit]

3.1 Extensions to the IFC standard

The IFC standard is currently available as IFC 2x, and it is today implemented in around 20 applications. [IFC Impl.] Version 2x is much improved from earlier versions. Still there is room for extensions and the list of ongoing projects is long. new extensions will include: HVAC performance validation, HVAC modelling and simulation, cable networks electrical installations, bridges, code compliance support, engineering maintenance, costs, accounts and financial elements in FM, material selection, specification and procurement and steel frame structures. There are also projects to include business transaction standards, classification framework and wooden projects.

These extension projects will not affect the core part of the standard, which has been fixed since version 2. All extensions will be domain extensions with extensive use of property sets. This is where the harmonization of IFC and ISO 12006 part 3 becomes highly important. Adding extensions to the IFC model as reference data in ISO 12006-3, will assure the standardization of domain specific properties and objects. The framework of ISO 12006-3 will prevent overlaps between domains and will link new extensions to national standards and classifications.

4 Implications of using the IFC standard

The IFC standard offers a new and much improved way of storing and exchanging information throughout the building process. It is however important to notice that not all applications support the standard. Today most sophisticated software that works with objects in 3D is already supporting the standard. [IFC impl.]

Using IFC in full scale in a project will demand special training of the people involved. There is a rather steep learning curve involved and similar tools might perform the same task different. It is however possible to use the standard as a pure file exchange without special knowledge. Tests done in Norway have shown that the IFC standard performs well and often better than de facto standards for pure graphical exchange. IFC should be seen as a supplement rather than replacement for existing standards. If two ore more participants in the process use tools that fully support the standard, IFC should be used for exchange between these. The use of the IFC standard should not be enforced on the participants if that implicated a total change of tools and techniques. With a gradual move towards model-based design the benefits will become obvious both for the participants and for the project owner.

The IFC standard as such has no competitors or alternatives. The standard is on its way to become an ISO standard under the umbrella of STEP [STEP]. This will guarantee backwards compatibility and stability on the same level as other STEP standards.

5 Conclusion

More and more data in the building process is exchanged as digital information. With the constant change and updating of computer programs and their storage formats there is a need for a fixed underlying conceptual data reference library with objects modelled independent of usage and language that is constantly added to meet new needs. Traditional paper based standards and classification tables will never be able to fulfil this role because of their structure and need of being kept unchanged for a longer period of time.

The IFC standard is adopted by the software industry. The big challenge now is to establish and adopt the IFC standard in the building industry, making it the default standard for information exchange. Working with product models will enforce new ways of organising building projects and distribution of work among the actors involved. More work will be focused in the early phases where the product model of the project is established. It is unlikely than an architect will put effort in producing a rich product model of the building if not getting paid for the extra work. The project owner should encourage the use of the IFC standard. The potential for time and cost savings with new workflows and business processes is significant. Estimates vary between 20% and 30%. [Bakkmoen] [Fischer]. The conclusion from several projects using the IFC standard is that despite the challenges, the benefit of using product model design is well worth the effort. [IFC Summit]

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[BARBi] Norwegian data reference library based upon the framework of ISO 12006-3. Project website at www.barbi.no

[Cornet] CORNET Singapore ePlansCheck. Construction and Real estate network. www.cornet.gov.sg

[EVE] EVE, Virtual Room. 3D visualization for decision-making. Helsinki University of Technology. www.eve.hut.fi

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[IAI Summit] IAI Summit 2002. Helsinki Finland, April 24 2002. http://cic.vtt.fi/niai/IAI_Summit_2002.htm

[IAI/IFC] Industry Foundation Classes (IFC) from International Alliance for interoperability (IAI). www.iai-international.org

[ICIS] International Construction Information Society. www.icis.org

[IFC Impl.] IFC implementers group. A complete list of existing and ongoing IFC implementations: www.bauwesen.fh-muenchen.de/iai/ImplementationOverview.htm

[ISO/DIS] ISO 12006-3 "Framework for object oriented information exchange" Developed by ISO/TC 59/SC 13/WG 6. www.icis.org/tc59sc13wg6/

[ISO15926] EPISTLE, The European Process Industries STEP Technical Liaison Executive: www.btinternet.com/~Chris.Angus/epistle/standards/iso15926.html

[Lexicon] Dutch data reference library based upon the framework of ISO 12006-3. Held at the STABU foundation: www.stabu.nl

[STEP] Standards for The Exchange of Product model data. ISO www.iso.org

Implementing Total Quality Management on Construction Sites

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Abstract

Quality systems entail having the organizational structure, responsibilities, procedures, processes and resources for implementing quality management such that there is a guiding framework to ensure that every time a process is performed the same information, method, skills and controls are used and practiced in a consistent manner. Total Quality Management (TQM) has been defined as a comprehensive systematic, integrated, consistent, organization-wide effort dedicated to customer satisfaction through continuous improvement. With its primary focus being the involvement of everyone, TQM has the potential to improve business results, greater customer orientation and satisfaction, worker involvement and fulfilment, teamworking and better management of workers within companies. Its ability to adapt to new ideas, tools and methods suggest that it can be applied albeit in an altered form to construction field operations involving workers at levels traditionally regarded as below middle management. However, the construction industry has been slow to embrace the concept of TQM. Construction firms have been continually struggling with its implementation. Historically construction has been an industry reluctant to implement change. Consequently it has remained behind where it should be on the implementation of TQM. Generally the principles of TQM are not applied beyond management levels within general contractors. There are few contractors that have fully implemented TQM at every level within their field organization, and even fewer at the field level of their subcontractors and suppliers. This paper reports on a study conducted in the United States to identify those factors that hinder the implementation of TQM principles in the actual field operations of a construction jobsite. These inhibitive factors were identified through a literature review and a survey of a sample of contractors.

Keywords

TQM; customer satisfaction; management commitment; paperwork; worker participation

1. Introduction

A cultural and behavioural shift in the mind-set of all participants in the construction process (Love and Heng, 2000; Kanji and Wong, 1998) especially top or senior management is necessary if the construction industry is to improve its performance and competitiveness. For innovation and continuous improvement to be encouraged and become a norm traditional practices need to be unlearnt. Historically the construction industry has been reluctant to implement change This process of change is especially difficult in the competitive environment in which construction takes place and where the bottom line is still the primary motivation of construction companies. Further, companies are prepared to only implement those aspects of Total Quality Management (TQM) programs that will provide them with competitive advantage and improve their overall financial performance. Ironically, research conducted by others such as Zantanidis and Tsiotras (1998) identified quality as being the most significant provider of competitive advantage. Construction companies clearly have not bought into this finding in their daily operations on site.

The authors conducted a study in the United States to identify those factors that hinder the implementation of TQM principles in the actual field operations of a construction jobsite. These inhibitive factors were identified through a literature review and a survey of a sample of contractors. This paper reports on these findings.

Participants in the study were asked to respond to several questions relating to the importance of certain criteria to the successful implementation of TQM in their companies. While only selected responses are discussed, the complete ranking of responses is shown in Table 1.

2. Management Commitment and Involvement

Almost all of the 109 valid[1] responses to the questionnaire survey regarded as important the commitment and involvement of their top or senior management in the TQM process for its successful implementation.

This finding accords with those of several other studies (Reed et al., 2000; Kathuria and Davis, 1999; Miller, 1996; Anderson et al., 1994; Tata and Prasad, 1998; Douglas and Judge, 2001; Saraph et al., 1989; Rahman, 2001). Management leadership is regarded as one of the categories needed for adoption as determined by the Malcom Baldridge National Quality Award in the United States. The pivotal role of top management for quality improvement programs is embodied in the working definition of Whiteman (2002) of TQM for construction firms which states,

"TQM is a continuous process whereby the top management of construction firms take whatever steps are necessary to enable everyone in the organization, especially construction field supervisors and construction workers in the course of executing all their activities on construction sites to establish and achieve standards, which include completion on time, within budget, to optimum quality

[1] SPSS labels those respondents "valid" that are included in the analysis after adjustment for non-responses.

standards, and without loss of life or limb, and exceed the needs and expectations of their clients, both internal and external."

Several studies have shown that the lack of upper or top management involvement or commitment to TQM is a stumbling block to its successful implementation (Schriener et al., 1995; Glover, 2000).

Table 1 - Ranking of responses of all respondents to TQM criteria

Rank Full Sample	**Criteria**	**Mean[2]**	**Std. Dev.**	**CV(%)[3]**
1	Top management commitment	3.98	1.20	30.2%
2	Top management involvement	3.78	1.29	34.1%
3	Primary customer focus	3.76	1.07	28.5%
4	Well developed planning	3.40	1.29	37.9%
5	Participative management style	3.22	1.28	39.8%
6	Continuous improvement measurements	3.04	1.33	43.8%
7	Rewards for TQM contributions	2.99	1.45	48.5%
8	TQM applied to all field operations	2.85	1.41	49.5%
9	Workers trained in TQM	2.71	1.35	49.8%

3. Customer Focus

All respondents regarded primary customer focus as the next most important requirement for successful TQM implementation. Several authors by definition consider customer focus as equally important as upper management involvement and commitment to TQM principles (Kelemen, 2000; BS 4778, 1991; Anfuso, 1994; AGC, 1992). In many studies, the issue of customer satisfaction or focus featured prominently as a defining concept or critical element of TQM implementation (Anderson et al., 1994; Shammas-Toma et al., 1998; Tata and Prasad, 1998; Douglas and Judge, 2001; Black and Porter, 1996; Rahman, 2001).

4. Participative Management Style

Participative management was an important criteria to the respondents in the implementation of TQM. This finding is well-supported in the literature (Kathuria and Davis, 1999; Young and Wilkinson, 2001; Ho et al., 2000; Stashevsky and Elizur, 2000). The importance of participative management is suggested by the notions of relationship oriented practices (Kathuria and Davis, 1999), employee fulfilment (Anderson et al., 1994), teamwork (Shammas-Toma et al., 1998; Black and Porter, 1996), employee involvement, empowerment and teamwork (Tata and Prasad, 1998; Kols and Sherman, 1998), employee relations (Saraph et al., 1989), people (Rahman, 2001; Yusof and Aspinwall, 2000), and human resource development (MBNQA). The

[2] On the scale used, 1= totally disagree, 2= generally disagree, 3= somewhat agree, 4= generally agree, 5= totally agree.

[3] Coefficient of Variation (CV%) is a quantity designed to give a relative measure of variability. The CV expresses the standard deviation as a percent of the mean.

lack of integration between TQM and human resource practices has been cited as a major barrier to achieving full-blown TQM (Glover, 2000).

5. Transfer of TQM from the Home Office to Field Operations

Most of the respondents had made efforts to implement the principles of TQM within their management operations. Relatively few of these firms (34%) had been successful in transferring this effort to their field operations. Unless TQM can be effectively implemented into field operations on site its benefits to the construction industry at large will be minimal. Since profits and losses are generated by construction activities on sites, improvement efforts have to be targeted at this essential area. In construction most of the workers of companies are employed on construction sites. Several authors maintain that workers need to be empowered and involved in TQM principles. They have argued for a shift in power from management to field operations (Richbell and Rasiatou, 1999); increased involvement of workers and increased contextual application of TQM principles (Glover, 2000); increased training of supervisors and hourly paid workers (Kassicieh and Yourstone, 1998; Chandler, 2000); and increased training in problem-solving and statistical process control (Marler, 1998).

Several key elements as shown in Table 2 were found to be major hindrances to the transfer of TQM to the field operations of construction companies.

Table 2 - Ranking of responses to TQM problem areas

Rank	Criteria	Mean[4]	Std. Dev.	CV (%)
1	Too much paperwork	3.44	1.26	36.6%
2	Subcontractors and suppliers not interested	3.39	1.24	36.6%
3	Low bid subcontracting	3.39	1.29	38.1%
4	Difficulty in measuring results	3.35	1.33	39.7%
5	Field employees regard TQM as irrelevant	3.31	1.20	36.3%
6	Transient work force	3.28	1.21	36.9%
7	Low education level of field forces	3.13	1.28	40.9%
8	Focus on short term cost savings	3.05	1.29	42.3%
9	Too tight scheduling	3.02	1.36	45.0%
10	No operations to benchmark	2.90	1.37	47.2%
11	TQM just a buzz word	2.83	1.39	49.1%
12	Too many uncontrollable factors	2.81	1.33	47.3%
13	Unique nature of construction	2.81	1.31	46.6%

The first six of these problem areas are briefly discussed in the next section.

6. Too Much Paperwork

[4] On the scale used, 1= totally disagree, 2= generally disagree, 3= somewhat agree, 4= generally agree, 5= totally agree.

Most of the respondents (77%) regarded the generation of too much paperwork through implementation of TQM principles as the most inhibiting issue to its success in the field. Most construction projects already involve large amounts of paperwork. These include voluminous contract documents, records of plans and amendments, architects' instructions, steel bending schedules, change orders, forms to record the requisition, order, delivery and movement of material, plant and labour, and material safety data sheets. Several authors support this view. Harari (1993a and 1993b) was concerned about the creation of cumbersome bureaucracies due to increases in paperwork to track the benefits of TQM programs. Lilrank et al. (2001) argue that excessive paperwork is prohibitive.

7. Transient Nature of Workforce

Similarly, most of the respondents (74%) stated that the transient nature of the workforce was restrictive to the implementation of TQM on construction sites. By its nature construction to a certain degree necessitates a transient workforce. Each project is built on a new construction site. Usually that site is not close to where workers had previously worked. Consequently workers will seek employment closer to home or have to relocate where this is not possible. Crosby (1990) suggests that companies need to work as hard on employee relationships as they do on their customer interfaces.

8. Field Employees Regard TQM as Irrelevant

A large proportion of respondents (79% of the sample) indicated that workers on construction regarded TQM as irrelevant to their performance. Schriener et al. (1995) suggested that obsession with the bottom line and seeing quality as merely an overhead might be contributory to this attitude. Further the exclusion of employees from quality improvement efforts and especially decision making relative to this improvement is a serious problem (Richbell and Rasiatou, 1999; Chandler, 2000; Senge et al., 1994). Other exacerbating factors include lack of proper training and continuous skills development (Katz, 1995; Wruck and Jensen, 1998; Reed et al., 2000), difficulty in generalizing training to opportunities to apply what has been taught (Marler, 1998), motivation of workers to want to improve their work (Hackman and Wageman, 1995; Katzenbach, 2000), and effective communication and project coordination (Shammas-Toma et al., 1998). Both construction managers and workers require a paradigm shift to a team approach (Shammas-Toma et al., 1998; Allan and Kilmann, 2001; Reed et al., 2000).

9. Difficulty in Measuring Results

Most of the respondents (75%) noted the difficulty in measuring results on construction sites as problematic for TQM implementation on those sites. Schriener et al. (1995) have suggested the lack of meaningful measurements as a major stumbling block. Whalen and Rahim (1994) and most TQM patriarchs from Deming to Juran echo these views. The assessment of quality is cited in the Malcolm Baldridge Award as being a critical feature of TQM (George and Weimerskirch, 1998). Wruck and Jensen

(1998) suggested several performance measurement systems that could be used such as construction cycle time, late delivery rates, and order lead times.

10.Low Bid Subcontracting

Similarly, most of the firms (74%) reported that low bid subcontracting presented a serious challenge to the successful implementation of TQM on construction sites. Low bid strategies have been the basis for awarding the majority of construction projects, especially subcontracts. This occurs despite the general contract being awarded on a different basis. Deming specifically advises that the practice of awarding business on price tag alone should be ended (Yong and Wilkinson, 2001). Schriener et al. (1995) also refer to this issue when they describe the obsession of companies with the bottom line as a stumbling block to TQM. Shammas-Toma et al. (1998) support this view. Glover (2000) refers to this tendency as business short-termism. According to Lahndt (1999), the construction industry's inherent competitive bid process and competitive environment has led to an emphasis on quick work and short time horizons, and a lack of long term viability and quality.

11.Subcontractors and Suppliers Not Interested in TQM

This issue was identified by the majority of respondents (65%) - only slightly below that of low bid subcontracting. For a TQM program to be successful, it has to be all-inclusive and comprehensive. In the overall sample, 26 of the 109 of respondents indicated that they utilized TQM principles in their operations. They did not have any formal TQM plans in place confirming the tendency of firms to only use selected parts of TQM programs. Wruck and Jensen (1998) and Douglas and Judge (2001) argue that the implementation of only selected parts of TQM programs threatens its successful implementation. Reed et al. (2000) contend that cross-functional communication that in the case of construction must include subcontractors and suppliers is necessary to solve quality problems. Shammas-Toma et al. (1998) suggest that effective teamwork is essential. To this end they argue that all parties must be bound together by mutually set and internalised goals rather than by contractual arrangements alone. The development of quality teams on the job site will lead to better support and quicker response to all members of the supply chain. By being part of quality teams subcontractors and suppliers will be more responsive to the needs of the general contractor, becoming more cooperative and displaying a better performance record (Wong and Fung, 1999). Subcontractors should be treated as partners (Kanji and Wong, 1998). As such they must be provided with all the information and support to enable them to carry out their work. A participatory approach involving all parties is advocated by the CIOB (1995) based on evidence in the Japanese construction industry. Ulrich et al. (1999) maintain that the value of the whole should be more than the sum of its parts. Kale and Arditi, (2001) point out that the General Contractor to be successful must consider the subcontractors and suppliers on the project as a strategic asset critical to the project, and the ultimate perceived performance of the General Contractor by the customer.

12.Conclusion

It is apparent that if TQM is to be implemented successfully on construction sites the inhibitive issues that have been identified from the literature and the contractor survey need to be addressed on a comprehensive and integrative basis. The principles of TQM should be applied beyond management levels and include workers on construction sites. These workers must be empowered, involved and trained in problem solving. Companies need to work on improving worker relationships in the same way that they do for their external customers. Through effective communication and improved project coordination workers must be motivated to improve their work. Contractors must move away from their obsession with the bottom line. They need to bind all parties together including subcontractors by mutually set and internalised goals. However, any attempt to bring about meaningful change with respect to implementing TQM on construction sites will only succeed if top or senior management commit and involve themselves in the TQM process.

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Human – Machine Collaboration to bring essential knowledge to the Inter-disciplinary Construction Team

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Abstract

To effectively consider the impact of environmental, quality and safety issues of major construction projects great emphasis must be placed on collaboration between the key disciplines thereby giving construction clients' best practice. But moving a fragmented industry with contract procurement systems that often breed discord and therefore do not always serve the best interests of the client, against a background of project participants who have different cultural backgrounds and working practices, requires high levels of integration and cultural change to achieve success. In problem solving, to arrive at a 'best' solution, both the people systems (the soft systems), and any computer support systems (the hard systems) require a partnership whereby each complements the other. To achieve such an environment requires new directions in providing the appropriate support systems. This paper outlines a new decision support environment that actively supports collaboration during decision making and problem solving activities of all participants' to the construction process. This environment is extendable to consider much of the criteria that effects new projects and provides a means for integrating the full professional team. A complementary partnership is formed between computer agents and human agents; the one bringing selected intelligence to the solution process from "unlimited" multi-domain knowledge sources, the other bring human cognitive rationality. In particular the system proposed articulates how domain knowledge and know-how can be shared thereby creating a truly integrating environment and breaking down barriers caused by either fragmented professional project team or lack of knowledge.

Keywords

Collaboration; Integration; Inter-disciplinary Team; Intelligent teamwork; Agents

1 Group problem solving

Group problem solving is characterised by more than two people being involved in attempting to reach a collective decision, each with their own perceptions, expertise and commitment towards that problem which they all recognise in varying degrees. Many problems that are solved in construction are resolved by a single domain rather than an inter-disciplinary team. This is well documented and construction industry research efforts over the past twenty five years have sort to find ways of effectively integrating construction decision making across the design and production professions. ‘Buildability’ and ‘Constructability’ are terms used in earlier attempts, then came a wave of expert system shells, then intelligent computer agents. The one common purpose was to find ways to bring additional ‘project’ knowledge to the design team so they might deliver to the client a solution that gave better value throughout the project life-cycle through a collaborating team of construction experts. Giving value from the construction services the client paid for by having the building solution developed concurrently rather than sequentially.

Some of this early research; Bui (1984) determined that group decision making can be undertaken in: [i] a co-operative environment where there is equality and respect for other opinions; [ii] in the non co-operative situation which is characterised by conflict and competition; [iii] in the group decision making situation where ultimately one particular manager makes the decision and assumes responsibility. Espejo (1991) considered that an individual expert working in a co-ordinated team to solve a defined problem would not always succeed if there were failure to communicate with other team participants. His evidence from observing designers at work brought him to the conclusion that there is a tendency for designers to concentrate on their local solution and ignore how their decisions will impact on others. One reason for this is human activities in problem solving are often influenced by individuals finding stability in interpersonal interactions rather than the single focus of achieving certain goals. There is overwhelming research evidence that to arrive at the ‘best’ solutions entail creating the conditions and environment for sharing experiences and developing an understanding of other domains viewpoint and criteria.

Gallegher (1990) calls this the concept of “intellectual teamwork”. He observes that information system designers working to create technologies that will help groups perform more effectively require not only technical expertise, but also an understanding of the social and behavioural processes that the technology is designed to support. Therefore, a collaborative computer-based design environment must not only rely on the hard system that selects stored knowledge at the appropriate time but must also reflect the soft systems approaches that lead to design excellence. The research carried out by the author, Jones (1998), Jones (1995) conceptualized such an environment. In it the inter-disciplinary team could be supported by computer agents to work towards building solutions in a collaborative way. The human/machine environment would be used to fully consider issues that effect bringing the best solution based on best practice to the client; issues such as quality, safety, cost, environmental factors, life-cycle effectiveness, performance, etc.

1.1 The Design Process

To understand how to build an effective support environment we need to understand how architects, engineers, construction managers and all the other inter-related construction disciplines work. What are their processes? How dependent is one disciplines process to another or how reliant should it be to get to the best solution? How can they be best supported? What do they need? Building design is a complex group problem solving process. Whitney (1990) stated that the process of design involves the simultaneous evolution of both the requirements and the artefact specification. However design-in-practice consists of many additional problems such as requirements analysis, negotiation, communication and conflict resolution.

Fundamentally the process of design is a complex activity involving a number of tasks that are generally broken into sub-tasks, with a number of alternative methods potentially available for each sub-task. Those design tasks are driven by certain input parameters, e.g. goals, preconditions, to produce some output parameters, e.g. layout, resources, constraints, etc. Chandrasekaren (1989) proposed that design be defined as a hierarchy of sub-tasks that can be solved by conducting a task analysis. A task-structure is then developed that lays out the relationship between tasks, applicable methods for solving the task, the knowledge requirements for the methods, and the sub tasks generated. How to break the design activity down into tasks forms a key area of research in task-oriented methodologies especially for knowledge-based systems and can be referenced in Pohl (1993) who defined that the architectural design process could be characterised by five functional elements:

- Information - a search for proper information that includes past experience of other projects;
- Representation - the methods and procedures designers utilised to solve design problems relied on their ability to identify, understand and manipulate objects. Objects have a representable form that encapsulates knowledge that is conveyed as factual data, algorithms, rules, exemplar solutions and prototypes.
- Visualisation - is important since traditionally some form of graphic media is used to convey design intention; generally this is in the form of drawings. Drawings however are often inadequate in portraying information and can lead to erroneous conclusions, with many misinterpretations and inappropriate conclusions resulting.
- Reasoning - which is central to the design activity. The ability of designers to solve problems is dependent on their interpretation of the issues and the dynamic changing relationship between these issues.
- Intuition - which in the design process is often the spontaneous reaction to a thought process that diverts too many areas of the human brain?

It is within these five areas that characterize the process used to develop a solution; a building or a structure. It is within these five areas that the partnership between machine and human agents should be one that each is complimented by the strengths of the other in an intelligent way. Humans use complex cognitive skills whereas machines are indefatigable in their mechanistic search for information that they bring to the collaborative environment.

Intelligence in the context of this work implies that the design system has some means that allows it to anticipate the data needs, information needs or knowledge needs of the human designer. The system would act as an intelligent assistant to the evolving design, aiding the designer and freeing them from being overwhelmed with untimely knowledge. Providing such assistance to all problem solvers in the design environment requires an understanding of the various participants' knowledge, factors that constrain their decisions and criteria they work under. Pohl (1993) called this an Intelligent Computer Assisted Design System (ICADS). The ICADS approach is supported in several working models (ICADS-DEMO1 (Pohl,1989), ICADS-DEM0 2 (Pohl, 1991), AEDOT (Pohl, 1992). These have provided computer scientists with a useful test bed for the development of a body of knowledge relating to software and hardware computer architecture, theoretical concepts and technical implementation issues. By linking the design objects to information they represent (e.g. functions, relationship to other objects, cost) the information value of drawings can be significantly increased. This information could be contained as attribute data in relational databases. Advances in the object-oriented modelling paradigm advanced this concept. Having this ability to view the artefacts used in the design model as a series of objects, which have implicit attributes and features, gives scope to analyse the design with regard to such aspects as manufacture, constructability, cost, quality, safety, etc., an almost unlimited definition of machine agents could be specified that caretake knowledge pertaining to most of the constraints and criteria related to a new building project.

2 Concurrent Engineering

Concurrent Engineering refers to the practice of incorporating various values of the product into the design at its early stages of development. These values address the entire supply chain of the product and include not only its primary function but also the manufacturing, marketing and operational stages of the production process. It is imperative that one of the goals of any machine/human partnership in building design must incorporate a concurrent engineering approach in the inter-disciplinary building team.

Howard (1989), found that the vertical fragmentation between project phases, (e.g. conceptual design, detailed design, bidding, construction), etc., and the horizontal fragmentation between participants, (e.g. architects, structural engineers, planners, estimators, builder, etc.), is unparalleled in any other manufacturing sector. Syan (1994) listed the weaknesses in the sequential method of product development as leading to:

[i] insufficient product specification, leading to excessive amount of modification;
[ii] little attention to manufacturability issues of the product at the design stage;
[iii] the estimated costing are usually degrees of magnitude in error, due mainly to the uncontrolled late design change costs which lead to a lack of confidence in the estimated costs of projects; and
[iv] the likelihood of late changes usually leads to expensive changes to tooling and other equipment.

Results reported from research, Turino (1994), indicated companies saw significant benefits in using a CE approach including 70% of participants reported a shorter time for their product to reach its market; 59% saw improved communications; 56% saw improved product quality; 33% saw reduced development costs and better management; 48% saw reduced design changes and 30% saw increased profits.

3 Collaborative Agent Partnership

The advances in the concept of an object as a high-level information source led to the paradigm of object-oriented modelling and the development of object-oriented computer languages. The premise is that a crucial element in the decision making process that human designers utilise to solve problems is the reliance they place on their ability to identify, understand and manipulate objects, e.g. architects develop solutions by reasoning about location, sites, buildings, floors, spaces, walls, windows, doors, and so on; the contractor does likewise. Each of these objects encapsulate knowledge about its own nature, its relationships with other objects, its behaviour within a given environment, what it requires to meet its own performance objectives and how it might be manipulated by the designer within a given design problem scenario. This knowledge is contained in the various representational forms of the object (e.g. factual data, algorithms, rules, etc.).

Within the computer agent environment, problem solving is seen as a co-operative process with mutual sharing of information to produce a solution. The resulting design solution is seen as an assembly of construction objects, e.g. bricks, walls, floors, windows, etc., these are assembled by human and machine agents to satisfy project specific criteria, e.g. quality, environmental, cost, safety, etc. Objects are information entities only whereas computer agents are active and have knowledge of their own nature, needs and global goals. Objects are accessible by agents but cannot take action. But for the system to interact effectively between the design intention and computer assistance there has to be a full description of the objects. This description should resemble as closely as possible the designer's real world by including the objects physical appearance, attributes, context and relationship to other objects.

In action within the computer environment agents also have the ability to communicate and take action. Typically, each agent is represented at the level of detail to which the designer wishes to reason about the designed system in the building project. The frames in such a project model could represent geometric, physical and administrative attributes of a project's components together with their topological structure. All of this information about the structure of a project and the local values of its component attributes are then available in a representation easily accessible by computer tools for solving or assisting with design tasks. A co-ordinator should be capable of invoking a procedure for resolving conflict conditions based on consultation. The agents use their specialised expertise and available resources to work in parallel on different or co-ordinating tasks to arrive at a solution concurrently.

There is an inevitable need for interaction between all the participants who input to complete the final project. Pohl (2000) suggested that the computer system should reflect the more realistic situation of a design team that interacts by co-operation and persuasion. The concurrent engineering concepts apply here. Therefore, complete families of computer-agents that represent a particular domain should be built e.g. architect, interior designer, civil engineer, landscape architect, safety manager, quality manager, environmental manager, mechanical and electrical engineer, construction manager, project manager, etc. and within each family specific agents would monitor and offer assistance regarding criteria and constraints imposed in the areas of environmental, quality, safety, cost, production time, etc. There could be a ‘Quality’ agent residing in a number of domains i.e. Architect, Construction manager, Project

Manager, Quality manager, each would be representing the criteria and constraints of that domain.

It must be stressed that this design assistance using computer agent is not intended to automate the design process. Agents would assist the designer in the partnership by acting as co-operative search agents having the ability to liase with knowledge bases in the search for alternative solutions. They are evaluators and solution proposers acting as system agents who operate in a defined domain. They exist to express opinions about the current state of the design solution. The intention is to change incrementally the current state of the design through the interaction among the various agents within the environment. This interaction enriches the environment with information about the current design state and how it relates to the design requirements. It should support the designer by providing adequate information about the current design state, its design objects (i.e., data-objects and object-agents), their relationships and how they satisfied the design requirements. Each agent would provide two kinds of support; intermittent foreground responsiveness to requests for information initiated directly by the designer, and continuous background monitoring and evaluation of the evolving design solution. The human agent's role in such an environment is seen as:

[i] Evaluating the current state, independently or with the support of other agents,

[ii] Participating in the process of changing the design state by manipulating the design objects, i.e. introducing new data-objects to the CAD environment, modifying attributes, etc.

[iii] Modifying the design goals if seen necessary,

[iv] Directing and guiding the effort of the other agents to advance the current state towards an acceptable design.

Operating in such an environment would be computer agent types as defined by Pohl (1994): System-agents resident in the design environment proposed would be: [i] expert-agents - which are a collection of domain specific system-agents that generate, synthesise, analyse, evaluate, criticise, recommend, explain, and optimise design related information (e.g. layout generator-agent, lighting-agent, cost-agent, safety-agent, acoustic-agent, quality-agent, geometric recognition-agent, explanation facility-agent). [ii] query-agents - who search for data in databases, knowledge bases and may be responsible for acquiring data from the data-objects while they are in a passive state.[iii] co-ordination agents - who provide co-ordination support for two or more interactive agents. [iv] activation/ deactivation - agents - responsible for creating an object-agent out of a data-object, or, updating the information of a data-object before the termination of its object-agent state. [v] CAD-agents - adding to and modifying objects in the CAD environment and their related behavioural attributes. [vii] The designer as agent - the designer can also be considered as a system agent. This is the principal agent who has control over the activities conducted by other agents in the system. [viii] Application support agent - is responsible for one or more operational support facilities, i.e. message management, process management or configuration management which allowed the designer to allocate resources, e.g. hardware and software or configure a needed component into the system, e.g. a new database.

4 The problem solving environment

In such an environment the design facilitator's role would be one of searching, evaluating and modifying the current design state with the support of different domains computer agent families (Jones, 1994). In this process the human agent would direct and guide the efforts of all computer agents to advance the current state towards a best design solution that is acceptable to all domains agents' and the human control agent. The role of the designer would be that of principal long term or strategic planner while agents would focus mainly on short-term activities, and therefore should be endowed with knowledge that enables them to only execute short term and reactive plans. The characteristics such computer agents would possess are:

(a) The agents would be programmed with appropriate problem solving protocols.

(b) Agents would only be considered intelligent when they possess the capacity to plan their own actions. Intelligent agents would therefore have implicit domain knowledge, knowledge of their own needs, knowledge of global goals, the ability to communicate and the ability to take action. They would also have access to objects, which are information entities, but unlike agents, cannot take action.

(c) A family of computer agents and objects would represent each domain and their problem solving activities associated with the design and production problems of a specific project. As other problems arise so the agent environment would extend or should the project be of a different construction then a new agent family would be appropriately designed (figure 1). In figure 2 an agent hierarchy in the domain of Construction Manager is shown.

(d) Sub-tasks resulting from decomposing the problem would be distributed to different domain agent families with the intention that these agents assist the human agent.

(e) Each domain family of agent would operate in a narrow domain providing support to requests for assistance. Agents would range from simple to complex processing units each rationally working toward a single global goal or towards separate individual goals that interact. Acting independently in a self-regulating manner their common purpose is to change the current design state towards meeting a common set of goals. The goals are set by the human agent(s) with advice from various autonomous agents that include agent representation of the client.

(f) Agents would use their local expertise and available resources to work in parallel on different or co-ordinating tasks to arrive at a solution in the following ways:

    (i) They would act as co-operative search agents, that liase with knowledge bases in the search for alternative solutions.

    (ii) Alternatively they would act as evaluators and solution proposers to express opinions about the current state of the design solution.

    (iii) Alternatively they would give continuous background monitoring and evaluation of the evolving design solution.

    (iv) They would be designed to have implicit domain knowledge, knowledge of their own needs, knowledge of global goals, the ability to communicate and the ability to take action.

    (v) Typically each agent would be represented at the level of detail at which the design facilitator or human agent wishes to reason about the designed system.

5 Conclusions

The partnership environment proposed is one that fully utilizes the strengths of a multi-agent collaborative computer environment and the human domain expert. A total design environment where the knowledge and intelligence of all domain-contributing agents can be employed, better opportunities therefore exist to concurrently view the effect of decisions that impinge on the many contributors. All contributors are collaboratively drawn into the design process. Time is saved because a concurrent problem solving approach is adopted rather than a sequential problem solving approach. Experts can still be geographically or functionally distributed, this also presents the opportunities to take advantage of recent technology in communication systems (co-operative distributed, broad band, etc.). The complexities of the design process can be broken down over numerous agents; problems can be decomposed to achievable sub-problems. Systems architecture for computer support of the design process can be more efficiently designed. Finally, the environment proposed could be extended to continually monitor and assist throughout the life cycle of construction projects.

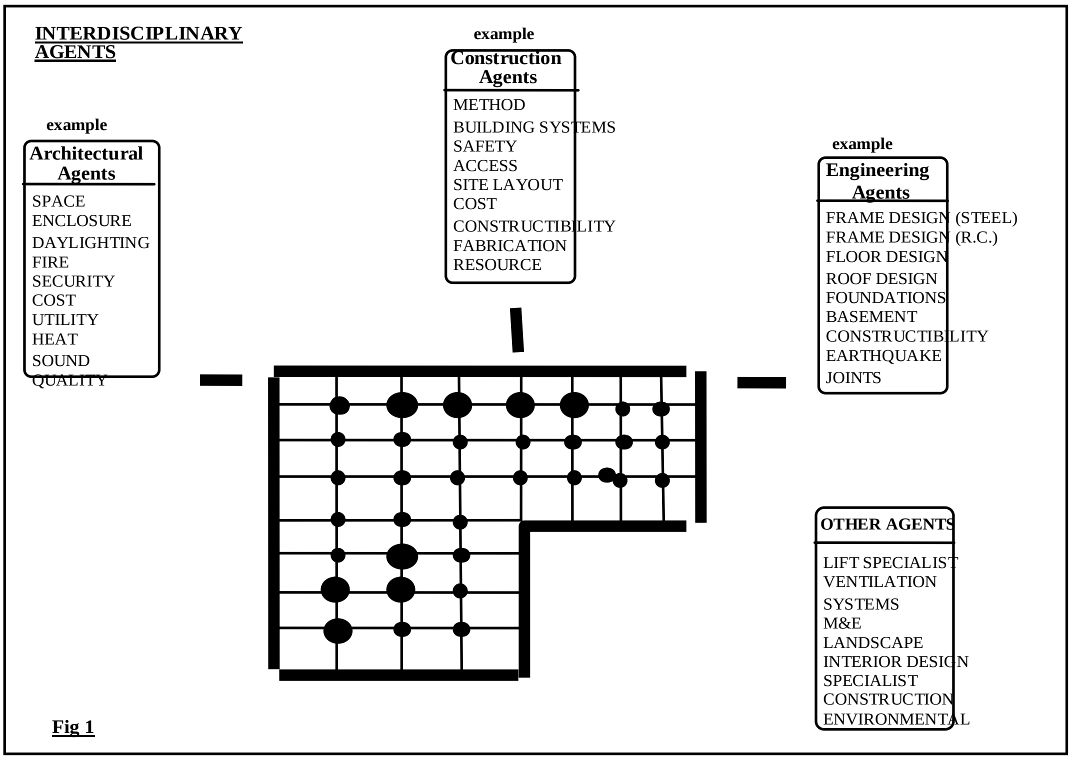

Figure 1 – Interdisciplinary Collaborating Agents

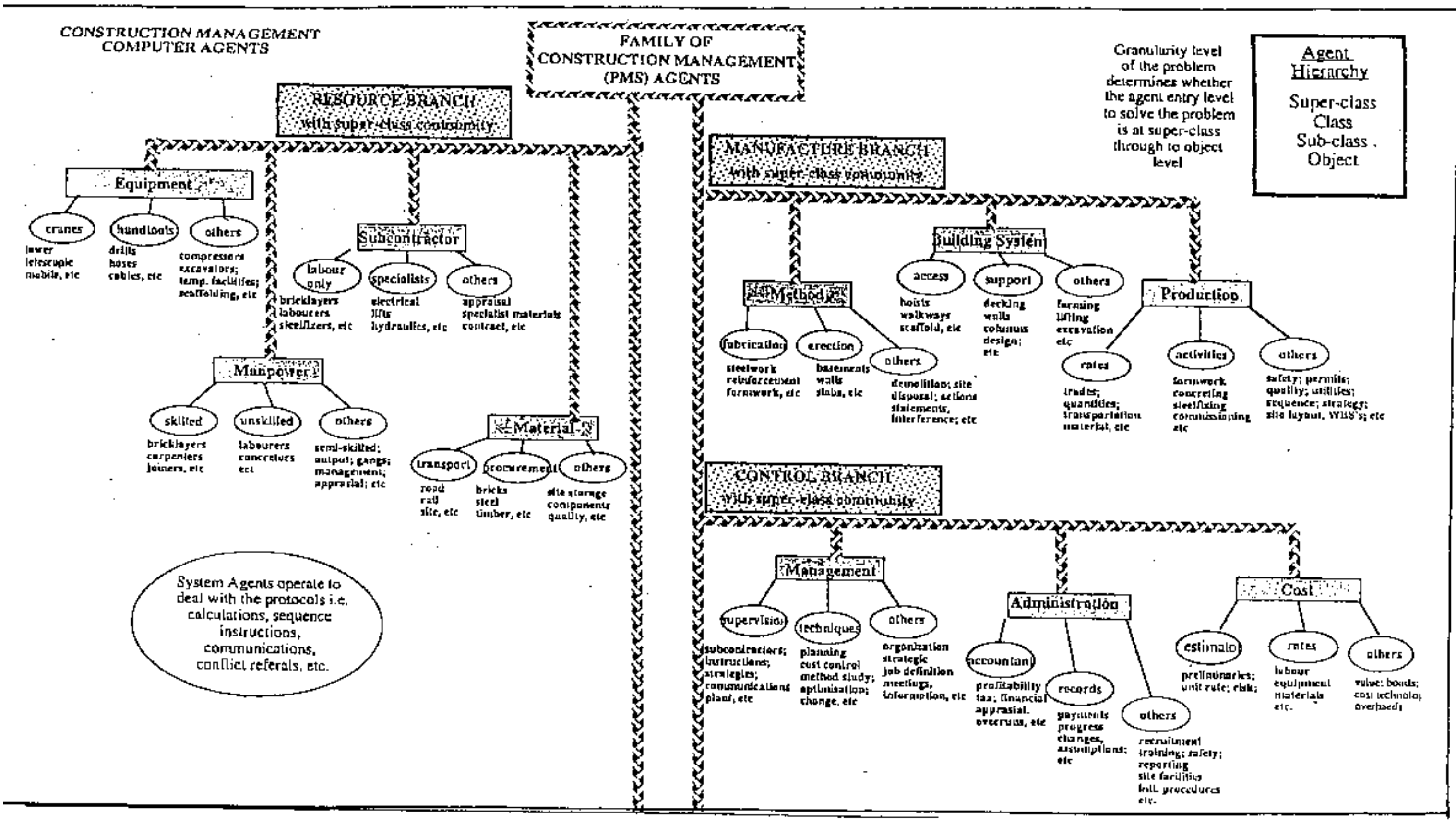

Figure 2 - Computer Agent Families – Construction Management

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Construction Safety and the Newly–established Legislation Framework in China

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Abstract

China is becoming the largest construction site in the world. With the appearance of a large number of construction companies running business with stiff competition among them, besides the introduction of new construction techniques and materials, the injury and fatal accidents occurred in construction sites ceaselessly. Meanwhile, the legislations related to construction safety are changing and consummating .Entrusted by the Ministry of Construction and the State Administration of Working Safety in China, this research on construction safety legislative framework was completed. Based on a comprehensive literature review and in-depth interview with legislators, government officials and other participants in the construction process, a clear picture of the up-to-date information relating to construction safety legislation in China was presented. After a brief review of the history of construction safety, the newly formed legal framework was described based on the empirical study. Several major problems have been identified and discussed, e.g. the unbalanced development of local legislation, prescriptive legislative provisions, and insufficient enforcement resources etc. Suggestions, such as the legislation system should be improved on the base of the three significant laws and owners should bear legal responsibilities, etc., were brought forth to promote construction safety in China.

Keywords

Legislation; construction safety; China

1 Introduction

Throughout the world, the construction area of civil engineering has been one of the most hazardous industries (Suazo and Jaselskis 1993). The construction industry is the second dangerous industry in China, while the coal mining industry takes the first spot (Fang et al. 2001a). As one of the oldest civilizations in the world, China has had a history of labour protection in construction for more than two thousand years. In the Song Dynasty (1,000 A.D.), there is evidence that carpenters erected protective curtains during the construction of a wooden tower to prevent workers from falling from height (Fang et al. 1999). In the early part of this century, with the development of both traditional and modern industry, the number of workers increased and the trade unions struggled in various forms for such rights of workers as greater salaries, less working hours, better labour protection and working environment (Fang et al. 1999). The Draft of Labour Protection Law, enacted in 1939, was a specific law on labour protection. The Draft stipulated specific organizations to supervise labour protection, measurement to protect women and juveniles, working time and so on.

After the foundation of P. R. China, the State Council enacted three regulations in 1956 based on practices in China and experiences of the former USSR. The three regulations are the Factory Safety and Health Regulation, the Safety Technical Code of the Construction Installation and the Reporting Regulation on Injury Accidents of the Employees (Zhang and Qin 2000). The resulting effect is clear that the fatal rate in the construction industry dropped from 56.0 fatalities per 100,000 people in 1958 to 16.5 in 1965 (Zhang and Qin 2000). From 1966 to 1976, however, the Culture Revolution in China made the whole nation plunge into chaos of the anarchy and serious economic depression. An upsurge of the construction accident rates came forth (Fang et al. 2001a). In 1970 the fatalities per 100,000 people reached 75 (Zhang and Qin 2000). After the Culture Revolution was over, the government began to pay more attention to managing construction safety. In May 1980, the Construction Ministry enacted The Safety Operation Technical Code For Construction Workers. In April 1981, Ten Measurements To Prevent Accidents Caused By Falling Objects were presented. Regulations such as Temporary Regulation To Strengthen Construction Safety Of Construction Companies, Construction Safety Regulations For State-Owned Companies, Safety Technical Code Of Electricity On Site and Scoring Standards for Construction Safety were compiled one by one. In 1990, the fatalities per 100,000 people cut down to 13.7. In the 90's, then came into the market a large number of construction companies and there was bitter competition among them. Innovative construction techniques and new materials have brought forward new challenges for the safety management. Many of the legislation relating to construction safety existed at that time were lagging behind and failing to provide support to the systematic and advanced safety philosophy. Subsequent to that, the construction safety legislation of China has been developed rapidly in the past decade. With the successional establishment of the Labour Law (1995), the Construction Law (1998) and the Law of Working Safety (2002), a comparatively integrated legislative framework related to construction safety has just been formed.

This paper presented a clear picture of the legislative framework relating to construction safety in China today. Major legislation newly enacted was introduced. Challenges encountered and suggestions on the base of problem discussion and international practices were summarized.

2 Background and Methodology

Since the 90's, the status and legislative framework of construction safety in China has changed a lot. Entrusted by the Ministry of Construction and the State

Administration of Working Safety, which was just established in 2001, this preliminary research on the construction safety legislative framework was carried out.

The focus of this research is to discuss major problems of the legislative framework related to construction safety and to put forth practical suggestions. The objects consisted of the national legislation passed by the National People's Congress (NPC), the local legislation passed by the Local People's Congress (LPC), the regulations established by the State Council and the rules and codes issued by the Commissions and Ministries in charge. The national legislation is the focus among them all.

Literature review and interview were the two principal research methodologies used. First of all, based on the review of all related laws and regulations, the problems existed were identified and analyzed. Problems included the vision and foundation of legislation, the form, effect and feasibility of the codification, and also the cost and effect of the enforcement. Furthermore, consultation with the directors and officials of the legislation and enforcement units, including Ministry of Construction (MOC), State Administration of Working Safety (SAWS), Ministry of Labour and Social Security (MOLSS), and 3 local Construction Safety Supervision Agencies (CSSA), was carried out. Interviews were also conducted with owners, contractors, academics and construction workers. Finally, practical suggestions were put forward baesd on international experiences.

3 The Legislative Framework Related to Construction Safety

3.1 The Labour Law

For the purpose of protecting labours' rights and interests and regulating the working relations, "The Labour Law of the People's Republic of China" came into operation on Jan 1 in 1995..

The Labour Law prescribes the basic rights and obligation of workers and the responsibility of employers roundly. This law consists of significant systems of working contract, social insurance, basic salary, working hours, holidays, labour dispute, and working supervision. The constitution and implementation of the systems is regulated firmly. Furthermore, the legal responsibility of the offender is publicized.

Labour Safety and Health, the 6^{th} Chapter of the Labour Law, prescribes the principles to deal with the safety and health problems that might emerge in the process of work. For example, "the employers have the duty to maintain safe and healthy working conditions", "the workers have the rights to work in a safe and healthy conditions", and so on and so forth.

Due to the huge amount of labour force in China, workers in the construction industry often work for low wages and long working hours (Fang et al. 2001b). Cases that breached the requirements of the law are common on account of the uncontrolled market behaviour and limitation of enforcement resources. Clauses related to safety are rather limited, which are too sketchy to be used for inspections or enforcement, Contractors will not be penalized unless serious accidents have happened.

3.2 The Construction Law

The Construction Law of the People's Republic of China came into force on March 1 1998.

The Construction Law prescribes that the Ministry of Construction under the State Council supervises correspondingly the nation's construction production and regulates the market behaviour of construction industry.

The construction safety management, the 5th Chapter of the Law, puts forward the specific prescription of the safety administration in construction industry. Firstly, it states that the construction safety management policy as "Precaution is the First Focus on Managing Safety". In addition, the safety requirement throughout the whole process of design, construction and dismantling, especially the principle that the contractors should obey, is clearly prescribed. For instance, "the contractors should take the responsibility of site safety", and "the education and training system of construction safety should be established". In order to ensure the safety of workers, the law also regulates that "the contractor must pay for the accidental injury insurance for the worker whoever undertakes risk tasks" and that "the workers have the rights to criticize, prosecute and accuse of the action that may bring hazards to their safety or health." As the elementary law to regulate construction industry, many clauses are not very specific but principle orientated. Consequently, the local legislation, which must be consistent with the Construction Law and the Law of Working Safety need to be more specific, should be established.

3.3 The Law of Working Safety

The Law of Working Safety of People's Republic of China just came into force on Nov 1, 2002.

As the principal law of the legislative framework for working safety, the law is regarded as the behaviour criterion, by which all kinds of enterprises, including the workers employed by them, should obey. Functioning as the foundation of governmental administration, the Law of Working Safety is also a powerful weapon to crack down on the illegal actions of employers (Shan, 2002).

Several primary juristic systems of working safety within all industries and enterprises are established and shown as follows (Shan, 2002).

1. The right and obligation of all parties, such as all levels of the government and the supervisory organ, the supervisory executive, the social organizations, the media, and so on, are prescribed.
2. The requirement for contractors to guarantee working conditions, management organization, investment on safety, qualifications of workers and the social insurance, etc, are prescribed.
3. The basic rights and legal responsibility of workers during the working period are prescribed.
4. The constitution of dealing with emergency plan and organization, the principle of investigation into the accident and the promulgation of the accident information, are prescribed.

In order to satisfy the needs of safety administration, this law prescribes more practical and pertinent measures and strengthens the punishment on the trespass (Li 2001). The effective scope of the law is defined with the following three statements:

1. The scope of working safety is limited in the industry field, different from the nation and public security.

2. Due to the speciality of fire protection and traffic, the corresponding safety legislation and regulations have been established thoroughly in those fields, where the Law of Working Safety does not cover.

3. What the Law of Working Safety does not prescribe should be regulated by legislation in certain industries, such as the Construction Law in the construction industry.

The Law of Working Safety, which is formed through widely solicited opinions, summarizing practices, investigating the feature and cause of significant accidents and referring overseas experience, is an advanced legislation in the field of safety administration (Li 2001). An obvious improvement in the composition of legislative clauses, however, was made from the Labour Law and Construction Law to the Law of Working Safety, in which the rights and obligation of workers, contractors, designers and inspectors, together with the punishment on the offenders, are defined in detail. As it has just come into force, the limitation and problems that exist have yet to be proven.

3.4 The legislation system should be improved on the base of the three significant laws.

The respective focus of each of the three significant laws is different: the Labour Law mainly concerns the welfare of the labour, no matter in which industry they work; the Law of Working Safety focuses on how to protect the employees' safety at work in all industries; the Construction Law pays more attention to the specific requirements of the construction industry and construction safety is just one part of the law. Anyway, these three laws jointly form the fundamental legal system for protecting the labours' welfare and safety in China.

Owing to the instructive and sketchy of the clauses in the laws, it is difficult to be enforced without specific regulations and technical codes prepared with reference to them. These regulations and technical codes, however, are neither sufficient nor well prepared. The philosophy of the laws cannot be fully embodied and the effectiveness is thereby limited. Completing the legislative framework with more sustaining regulations and technical codes concerning construction safety is still a main task of the MOC and SAWS in the future (Zhang and Qin 2000; and Zhang 2002).

On the other hand, there are large economical gaps among different provinces in China. Hence, the major problems of construction safety management encountered by various local governments are quite different. Nowadays, the local safety legislative framework of the big cities, such as Beijing, Shanghai, Shenzhen, has been developed quite a lot. Some good practices were introduced nationwide. For example, "the Civilized Sites Campaign" originally practised at Shanghai for improving the physical environmental and safety conditions on construction sites has been an important part of the National Standard of Construction Safety Inspection (1999). While in some lagging behind districts, the speed of establishing local construction legislation is rather slow. Accordingly, to complete the local legislation on the base of the three significant laws is of prime importance.

4 Challenges to Construction Safety

The points of view below were formed and summarized on the foundation of interviews with the people aforesaid.

4.1 Unbalanced development leads to the difficulty of the legislation.

The per capita Gross National Product (GNP) in construction industry in 1999 is RMB15, 320, which is much lower than the average per capita GNP RMB24, 894 in industries in China (CSP 2001). It is pointed out that when comparing the level of economic development measured by the per capita (GNP) to fatal accident rates, it is clearly evident that low productivity is linked to high fatal accident rates (Takala, time and original journal of publishing not clear). More importantly, under the pressure of economy development, less attenttion is paid to workers' health and safety in the economically laggard provinces, so the principal philosophy of the laws cannot be fully embodied. Furthermore, the economical disparities among different provinces of China are getting larger and larger, especially between the east coastal regions and the west terrestrial regions (CSP 2001). For example, the GNP of Guangdong Province in 1999 is RMB 846 billion, while the GNP of Tibet Province is RMB 11 billion. Since large economic gap exists, the establishment of legislation and codes must take into consideration of both the advanced and behindhand provinces. More local regulations with higher standards should be developed in the advanced provinces, while the laggard provinces should make greater effort to meet the minimum demands of the legislation.

4.2 The provisions of the legislations and regulations are prescriptive approaches.

Nowadays, the provisions of the laws related to construction safety are prescriptive approaches, which are also called "deemed to comply" or "command and control" provisions. The prescriptive approach describes means, as opposed to ends, and is primarily concerned with type and quality of materials, method of construction, and workmanship (CIB, 1982). It attempts to standardize the work process using prescriptive rules and procedures usually backed by the monitoring of compliance and by sanctions for non-compliance.

The prescriptive legislations have three problems, however. Firstly, the legislation framework of China is far from consummation. Compared with that of the USA, who also enacting prescriptive laws, Chinese legislation framework is quite different and laggard. Detailed regulations and technical codes are inadequate in many areas related closely to the construction safety. Secondly, it is impossible to refine the provisions to keep pace with innovation, better construction techniques, and new materials. The reason is that the changing process of the laws is complex and rather slow, while the construction industry is progressed rapidly from year to year. There left many holes in the system and new hazards are left uncontrolled. Thirdly, more inspectors and enforcement resources are needed when applying the prescriptive legislation. While, the legislature always failed to provide adequate funds for enforcement in China.

The Council Directive 92/57/EEC in Europe and the Construction (Design and Management) Regulations (CDMR) in the UK, National Model Regulations and the National Code of Practice for the Control of Workplace Hazardous Substances in Australia, etc, are all performance based nature legislations. The health and safety outcomes are specified in the regulations, but not the means to achieve them. It is anticipated that the paradigm shift promoted by this type of regulatory framework will have positive results for the construction industry and contribute to the common vision of accident free construction sites (Haupt and Coble 2001). The merits of performance based approaches should be considered when developing the safety legislation of China.

4.3 The enforcement resources are not sufficient.

Without effective inspection and strict punishment, the tenet of the legislation cannot be fully embodied. Nevertheless, efficient enforcement needs sufficient inspectors and funding. Since the No.13 Order, "Regulation of Construction Safety Supervision", issued by the Ministry of Construction in1991, the cities of more than 25 provinces have established local Construction Safety Supervision Agencies (CABP 2000). The State Administration of Working Safety also has established local Administration of Working Safety in more than 19 provinces (Zhang 2002).As most of these local agencies have just established for several years, the number of officials is very limited. Besides, they in fact are mostly engaged in dealing with all kinds of accidents and have little time to do more efficient enforcement work, such as inspection. In order to make full use of the limited number of officials, the enforcement strategy should be adjusted according to the past safety performance, technical complexity, construction phase and others of the sites. OSHA of USA has adopted the strategy of target inspections using data-driven approaches to address the hazards, industries, and occupations identified by OSHA's performance goals (OSHA 1998). This efficient strategy can be considered when legislating.

As there is almost no governmental funding for the Local Safety Supervision Agencies, the agencies must assume sole responsibilities for their profits or losses. In order to maintain operational, these agencies will have to make profits in different ways. For example, charging contractors for Supervision Fee, obliging contractors to buy construction accidental injury insurance from certain insurance companies and sharing the profits with the companies. Such compelling measurements affect the visualization and function of the safety agencies. In fact, as governmental agencies for maintaining the stabilization and development of the society, like police and other judicatory systems, the safety agencies should be considered by the legislature to apportion adequate financial funding.

4.4 The owners should also bear legal responsibilities.

Because the Construction Law of China (1998) states that the contractors should take the whole responsibility for site safety, the owners would not think much of the safety. Certain owners may emphasize safety before work commences, but as the work progresses their concern for completion deadlines or the quality becomes a priority and they tend to pay less attention to safety. Such situations are particularly common in China since the traditional culture emphasizes completing the construction to celebrate some special festivals or political events. Many projects are required by the owner to be completed before a strict and sometimes even absurd deadline in order to make celebrations on time. Owing to these unreasonable construction schemes, many more accidents happened.

Furthermore, the construction market in China is a buyer's market, as a result of the booming of the construction companies, which reach the total number of 97,263 in 2000 (CSP 2001). The contractors usually have to reduce their bid price as low as possible, sometimes even lower than the costs, in order to acquire the contract. The competitive tendering results in that the contractors who have managed to win the contracts are forced to reduce the project costs. Since the severity of injury incurred is largely a matter of chance (Heinrich 1980), many contractors choose to cut down safety investment. However, this is partly for the owners' chronic unreasonable bargain. The illegal behaviour of the owner is a big problem that leads to injury accidents. Therefore, it is crucial to put the owners' legal responsibilities in the law, as what happen in UK (HSC 1994) and Taiwan (Koehn et al. 1995).

4.5 The responsibility system of construction safety has no substantial effect.

The Construction Law and Law of Working Safety both prescribed clearly that each construction corporation in China should establish and consummate responsibility system of construction safety. But three problems make the legislation less effective. Firstly, the laws asked health and safety to be the sole responsibility of the contractor, while Ngowi and Rwelamila (1997) pointed out that the exclusion of health and safety from specifications, and health and safety being the sole responsibility of the contractor has been identified as the primary cause of accidents in construction. Secondly, both the inspector and contractor do not really pay attention to the system. The safety responsibility systems of many corporations, which are normally written on paper and put in the drawer for manipulating inspectors, lack of practical detailed prescriptions. Last but not least, the state-owned construction companies bring much intricate contradiction. If accidents happen, there is no efficient measure to punish the corporations at fault. On one hand, the corporation cannot simply be punished as a whole, because strict punishment means the corporation may have to pay out a lot of money or even bankrupt. Then many workers will lose their jobs. The high unemployment rates will lead to instability of society, which is contrary to the central government's primary strategy of maintaining stability. On the other hand, although it is regulated that the juridical person of the corporation should bear the responsibility for the accidents, usually critique, demotion and low-sum-forfeiture are the main measures to sanction him. Very seldom will criminal liability be pursued. The proactive effect of the responsibility system is therefore absolutely insufficient.

4.6 The workers should not be trained only by the contractors.

According to Culver (1992) the most significant finding from Occupational Safety and Health Administration (OSHA) research which investigated approximately 360000 accidents was that the accident rate was higher for less experienced workers. Also, the relationship between health and safety training and performance is quantified by research conducted in Saudi Arabia by Jannadi and Al-Sudairi(1995) which determined that the safer firms all provided new workers with formal health & safety training.

The three significant laws have stipulated clearly that the contractors have the legal liability to train new workers or workers who have been transferred to new posts. As a matter of fact, effective safety training needs some costs. Under the highly competitive marketing circumstances, most contractors feel reluctant to invest in safety training. Even if in the Zhujiang Delta, the richest district in China, the investment on training of each construction projects only takes only 1% of the total safety investment, which takes about 2.5% of the project costs (Chen 2002). Moreover, since the workers change their jobs frequently, the training offered by the corporations are always like mummeries. Commonly the foreman reads part of the basic technical codes to the workers, while probably he himself never received any safety training. Such kind of mummery certainly has little effect to cut down accidents. As no widely accepted standard or related regulations exist, the contractors who do not offer training at all need not worry about being punished.

In order to improve this undesirable situation, the Green Card system enacted in Hongkong is a good pattern to be introduced (Rowlinson 2000). Under the Green Card system, each construction worker must receive safety training offered by Construction Industry Training Administration (CITA) or other training provider, accredited by the government. Only if a worker has passed the training examination, can he get the Green

Card and work at construction sites. The cost of the training can be included in the project bidding price according to the number and categories of future employed workers.

4.7 The system of Workers' Compensation Insurance (WCI) has just commenced.

To the dangerous industry as construction, the development of WCI has greatly enhanced the improvement of safety performance, because it works as an important economic incentive for contractors to improve safety management. Contractors with better safety records will pay significantly lower costs for workers' compensation (Levitt and Samelson 1993). The system of WCI is now widely used all over the world.

All the three significant laws in China also clearly stipulated that contractors must insure workers involved in dangerous jobs and must pay the insurance premium. The rights and interests of construction workers are well protected with the enactment of these laws. Nevertheless, the industries of both construction and insurance are not yet fully developed in China (Fang 1997). Experiments are being made in a few provinces and some problems encountered.

For example, even in Shanghai, the most economically developed city in China, many problems do exist. The first problem of the system is that contractors cannot choose insurance company freely. The local safety supervision agency designates the insurance company to which the contractors should pay the premium, because the local agency and the insurance company have signed a contract to take a part of the premium jointly. Secondly, the fixed premium rate means that the safety performance of the contractor will not affect his total costs. The contractor has no motivation to improve his safety performance, so the proactive effect of the insurance system is lost. Thirdly, since worrying about being punished administratively, losing their reputation or refusal by the insurance company; only a small part of contractors claim compensation after accidents. It is estimated by the official of Shanghai Construction Safety Supervision Agency that only 20% of the total premium is used to compensate leaving behind substantive profits. But in the developed country, the accidental injury insurance normally has little profit, or even no profit.

4.8 The labour union does not serve the worker well.

Anecdotal evidence suggests that it is not just management participation and involvement in safety activities that is important, but the extent to which management encourages the involvement of the workforce (Niskanen 1994). The higher the level of workers' involvement in safety matters, the more positive the safety climate (Mohamed 2002). Both OSHA of USA and HSC of UK are going to enhance worker involvement in all aspects of safety and health at the work place in their latest strategic plans (OSHA 1998; HSC 1999).

The Law of Working Safety prescribes that the labour union should make arrangements for the worker to participate in democratic management and supervision of working safety and maintain their legal rights and interests of working safety. Although each corporation has its own labour union, little is done to protect the health and safety rights and interests of workers. The reason is that the leaders of the labour union are commonly retired corporation managers or persons who are appointed by the contractor but not elected by the workers, besides they receive salary from the contractor. Not enough extrinsic motivation for the leaders to make great efforts to improve workers' health and safety environments.

4.9 The supervisory effect of people at large and media should be strengthened.

In the development history of the safety management in USA, the consensus supervision of people at large and media operated magnificent force on the improvement of the safety management (MacLaury 2002).

In China, the effect of consensus supervision is very limited. On the one hand the people or institution that bears legal liability blank off information painstakingly, meanwhile, the media is not sensitive enough to accidents. On the other hand, the system and method for the masses to complain about violations of the law to the governmental supervisory units are not well established.

The Law of Working Safety for the first time prescribes the rights of the masses and media to supervise the behaviour which offends the related safety laws and emphasizes the liabilities of all levels of governments to establish complaining system, publicize the complaint phone number and deal with the complaints. It is an improvement in the legislation aspects of working safety in China.

5 Summary and Conclusions

A clear picture of the legislative framework in China today is provided. Based on the description of the framework, the problems encountered have been identified and discussed through the empirical study. It is clear that although the legislative framework has been improved a lot since the establishment of People's Republic of China in 1949, there is still a long way to consummate it. Using the international practices in the construction safety management as reference, the following suggestions are listed:

- More regulations and technical codes that support the three significant laws should be developed.
- The economical basis of the legislation should be considered.
- The merits of performance based approaches should be considered when developing safety legislation of China.
- Target inspections should be developed and adequate financial funding apportioned by the government.
- The owners should also bear the legal responsibilities of construction safety.
- The responsibility systems of construction safety should have more proactive effect.
- The workers should be trained jointly by the contractors and agencies audited by the government.
- The accidental injury insurance should be developed on the base of adjustable premium rate.
- The workers' involvement in safety issues should be encouraged.
- The supervisory effect of people at large and media should be strengthened.

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