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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