International conference on

costs and benefits related to quality and safety and health in construction

Barcelona, Spain. 22-23 October 2001

proceedings

Edited by Miquel Casals

Edited by: Miquel Casals

Published by: Information, Image and Publications Service, 2001 (6149)

Legal deposition: B-40.222-2001

ISBN: 84-7653-790-5

Disclaimer

The publisher makes no representation, express or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability in whole or in part for any errors or omissions that may be made.
The reader should verify the applicability of the information to particular situations and check the references prior to any reliance thereupon. Since the information contained in the book is multidisciplinary, international and professional in nature, the reader is urged to consult with an appropriate licensed professional prior to taking any action or making any interpretation that is within the realm of a licensed professional practice.

PREFACE

These are the edited Proceedings of the International Conference on Costs and Benefits related to Quality and Safety and Health in Construction organised under the auspices of the CIB Task Group TG 36 (Quality Assurance) and the Working Commission W99 (Safety and Health on Construction Sites). It is held at the Universitat Politècnica de Catalunya in October 2001.

The Conference is intended to create an adequate forum for to discuss economic aspects of quality and safety and health in construction. It provides an opportunity to showcase the current practices in each subtopic area and to measure global activities in (non) quality and (non) safety and health costs.

The aim of the Conference is to provide a forum for exchange experiences on these topics, and will be a good opportunity for all those involved in the construction process to learn about the work being done in different countries and to mutually benefiting from their results. Therefore, it is a fitting place to discuss these and other related issues.

CIB aims to stimulate this discussion.

The organisers

Miquel Casals (Spain)
Luís Alves Dias (Portugal)
Richard Coble (USA)
Tapio Koivu (Finland)
Gary Smith (USA)

ACKNOWLEDGEMENTS

The organisers would like to express their gratitude to all authors and to the colleagues who chaired the sessions for their valuable contributions. Special thanks go to the members of the Technical Committee and to the Keynote Speakers for their significant support and assistance in the organisation of this Conference.
The organisers are also gratefully acknowledge the organisations that sponsored this Conference, which contributed significantly to the recognition viability of the Conference.

CONFERENCE ORGANISATION

Organisers:

Prof. Miquel Casals, Universitat Politècnica de Catalunya - Spain
Prof. Luís Alves Dias, Instituto Superior Técnico, Technical University of Lisbon - Portugal
Prof. Richard J. Coble, CIB-W099 Coordinator, University of Florida – USA
Prof. Gary Smith, CIB-TG36 Coordinator, North Dakota State University - USA
Dr. Tapio Koivu, CIB-TG36 Coordinator, VTT Building Technology – Finland

Scientific and Technical Committee:

Dr. Alistair Gibb, ECI, Loughborough University of Technology, UK
Dr. Amarjit Singh, University of Hawaii at Manoa, USA
Prof. Arie Gottfried, Polytechnic of Milan, Italy
Prof. Gary Smith, North Dakota State University, USA
Prof. Gonzalo Ramos, Universitat Politècnica de Catalunya, Spain
Prof. Howard Bashford , Arizona State University, USA
Dr. Ib Olsen, Ministry of Housing and Building, Denmark
Prof. Jimmie Hinze, University of Florida at Gainesville, USA
Dr. John Smallwood, University of Port Elizabeth, South Africa
Prof. Luís Alves Dias, Instituto Superior Técnico, Portugal
Prof. Miquel Casals, Universitat Politècnica de Catalunya, Spain
Dr. Nancy Holland, Texas A&M University, USA
Dr. Naoto Mine, Institute of Technology Shimizu Corporation - Japan
Dr. Odd Sjøholt, Norwegian Building Research Institute, Norway
Dr. Peter Love, Deakin University, Australia
Prof. Pere Alavedra, Universitat Politècnica de Catalunya, Spain
Prof. Richard Coble, University of Florida, USA
Prof. Silvio Melhado, University of S. Paulo, Brazil
Dr. Tapio Koivu, VTT Building Technology, Finland
Dr. Theo Haupt, Peninsula Technikon, Bellville, South Africa
Prof. Wim Schaefer, Eindhoven University of Technology, The Netherlands
Prof. William Maloney, University of Kentucky, USA

Scientific and Technical Secretariat:

Miss. Núria Forcada. Universitat Politècnica de Catalunya – Spain

TABLE OF CONTENTS

PROCEEDINGS

Costs and Benefits related to Quality and Safety and Health in Construction

Monday, 22 October 2001

TOPIC: Management of construction Quality and Safety and Health costs.

CORPORATIVE KILLING AND THE ROLE OF SENIOR MANAGERS IN ACCIDENT PREVENTION

Andrew R Atkinson
South Bank University, London, United Kingdom
atkinsar@sbu.ac.uk

As a result of several major industrial and transportation accidents in the United Kingdom, the UK Government is considering changing the law relating to involuntary manslaughter where gross negligence by managers leads to the death of employees or members of the public. Proposed penalties include fines, disqualification and imprisonment (Law Commission, 1996, Home Office 2000, APIL 2000). Compared with recent measures, this represents a change in approach from bureaucratic rules and procedures to a greater emphasis on imposing personal responsibility for negligent actions. However, the imposition of personal responsibility must not to be seen simply as retribution. The change should both be effective and produce measurable benefits. Developments in the multi-disciplinary study of human error, support the effectiveness of the change and this paper reports a cost/benefit study, which also indicates that provided there is a modest reduction in fatalities, custodial sentences for corporate killing should be economically effective.

Key words: Human error, corporate killing, construction, management, personal responsibility

By international standards, Britain has an excellent workplace safety record. Although international comparisons need to be treated with caution, figures for 1996 (Table I) indicate that, of several European countries and the USA, only Finland has a lower rate of fatal and serious injuries. The British record for the construction industry is equally good (Table II). Additionally, there has been a consistent decline in the construction industry injury rate from the early 1980s. This steady improvement has been attributed to the introduction of legislation covering workplace safety dating from the UK Health and Safety at Work Act 1974, including the introduction of the Construction (Design and Management) (CDM) Regulations 1994 (HMSO 1994, HSE 2000B). It suggests that the British safety system can act as the model for improvements in other countries. However, recent trends in accidents in the British construction industry are worrying. Figure 1 shows a large increase in construction industry deaths for 2000/2001 marking an abrupt end to steadily improving figures. This is so on the number of fatalities per 100 000 employees and on the number of fatalities per £ billion of construction industry output. The "bottoming out" of figures provides support for the fatalist view that "zero accidents" is an unattainable objective, that there will always be accidents in the construction industry, or that the eradication of accidents will be overly costly.

Table I. Workplace Injury in Europe and the USA 1996

Country	Rate of fatal injury	Rate of over 3 day* injury
Finland	1.70	3400
Great Britain	**1.90**	**1600**
Sweden	2.10	1200
Netherlands	2.70	4300
USA	2.70	3000
Denmark	3.00	2700
Ireland	3.30	1500
Germany	3.50	5100
EU Average	**3.60**	**4200**
France	3.60	5000
Greece	3.70	3800
Italy	4.10	4200
Austria	5.40	3600
Belgium	5.50	5100
Spain	5.90	6700
Portugal	9.60	6900
Luxembourg		4700
* Leading to an absence from work of more than 3 days		

(Source HSE 2000A)

A counter argument is that the levelling off of the accident rate indicates that "zero accidents" in construction may still be attainable, but that present strategies of accident reduction are reaching the limits of their usefulness. In order to obtain further reductions, it is necessary to look beyond current practice in the construction industry and to examine developments in other industries and academic disciplines. In particular, it is informative to review developments in high risk industries, such as transportation, nuclear power generation and mineral extraction, where the occurrence of accidents is infrequent, but the consequences are dramatic, and in academic disciplines where the consideration of accidents is from a human error perspective.

A human error approach to accidents

One of the most consistent findings from studies of human error is its inevitability (Rasmussen, 1983, 1990, Reason 1990). Reason (1990) attempts to explain the inevitability of error as the consequences of a trade-off in the mind between spccd of information processing and its accuracy. Petroski (1994) takes this further in proposing the beneficial effect of error and experimentation, where experience from errors can be used to improve subsequent performance. The consequence of considering errors to be inevitable has led to several authors from a variety of perspectives, to propose that they should be managed. A common approach is to divide errors leading to failure into two. "Active" errors are directly perpetrated by workers carrying out operations and are the most obvious and immediate cause of failure. "Latent" errors are related to supervisory actions and may contribute, or lead to the occurrence of an active error.(Reason 1990, Petroski 1994, Kletz 1985, ACSNI 1993, Bea 1994 Blockley 1992. Whittington et al 1992).

Table II. Rates of Fatal Injury in the construction industry for five European countries 1996

Great Britain - 96/7	5.6
Great Britain - 97/8	4.6
Germany	8.6
France	20.8
Italy	17.6
Spain	28.9

(Source HSE 2000A)

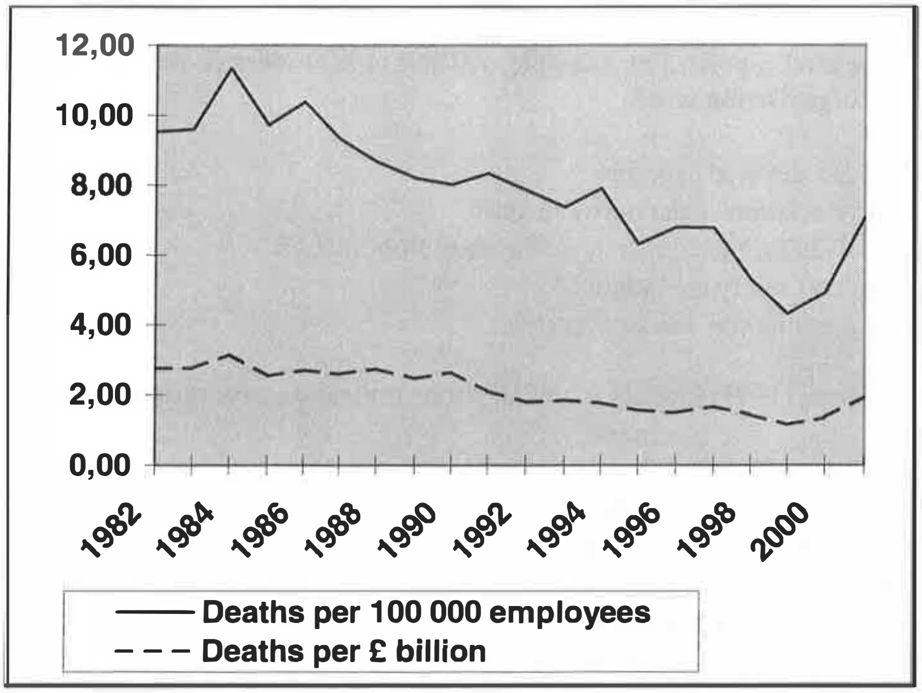


Figure 1. UK construction industry fatalities 1982-2001
(Sources - ONS 1990, NS 1997, 1998, 2001, HSC 1993, 2000, HSE 2001)

LATENT ERROR PREVENTION

Although much of the thinking on human error originated in the discipline of psychology, the development of policies and techniques of latent error prevention has largely been a multi-disciplinary endeavour loosely grouped under a management heading, but viewed from a variety of perspectives including:

- Reliability engineering and systems safety (Embrey 1992, Harrison 1992)
- Interdisciplinary reports (HSE 1976, ACSNI 1993, Bea 1994, Blockley 1992)
- Systems theory (Fortune 1984, Fortune and Peters 1995)
- Total quality management (Oakland 1998, Bell et al 1994)
- Project management (Morris 1994)
- Engineering management (Petroski 1985, 1994, Kletz 1985, 1993)

Analysis of these perspectives reveals a number of common characteristics of errors in modern organisations as well as a remarkably consistent set of classes of latent error giving rise to accidents. Authors stress that organisations have to be considered as complete socio-technical systems in analysing cause and closely linked to this is the fact that, especially for major failures, multiple errors are involved at different levels within an organisation. Commonly identified classes of error include poor supervision and checking of subordinate's work, poor control of changes in both design and operation, poor division of responsibilities

giving rise to gaps and overlaps in duties, poor formal and informal communications again giving rise to gaps and inconsistencies between documents/instructions.
The importance of "organisational culture" is widely stressed and its components are identified in several reports. For example, ACSNI (1993) identify the indicators of a "safety culture" in an organisation where:

- Resources are devoted to safety
- Participative relations exist between staff
- Visibility of senior management on the shop floor is high
- Production and safety are balanced
- There is a participative leadership style.

Fortune and Peters (1995) identify a similar list as critical success factors in project work:

- Resources are sufficient
- Control mechanisms are in place and used
- Project has support of top management
- Communications channels are adequate
- There is capability for feedback
- Contractors are responsive to clients

Neither authors indicate just how the "safety culture" or "critical success factors" are to be achieved and the achievement of an organisational culture appropriate to "zero accidents" remains an elusive aim.

The UK CDM regulations and the European Directive (EEC 1992) driving the UK legislation appears to address some, but not all of the error factors identified above. In requiring the appointment of a planning supervisor and principal contractor, the legislation is centralising responsibility for safety, but with a specialist safety officer and not with line managers. Likewise, the requirement for a pre-tender health and safety plan, which is subsequently developed by the principal contractor addresses some of the problems associated with poor change control and division of responsibilities. Planning is generally directed towards controlling these factors and some research (Hinze and Raboud 1988) suggests that better and more sophisticated planning of construction sites leads to a lower accident rate. However, the regulations are bureaucratic and do not address problems related to poor organisational culture. They also perpetuate the myth that safety is somehow separate from other management functions and is a cost rather than a benefit. To address these problems it is necessary to turn to another set of literature, largely based in sociology, but with some reference to total quality management.

ORGANISATIONAL CULTURE

Sociologists have given considerable attention to the concept of organisational culture in the context of major accidents and some give indications of the components of a positive safety culture and how it might be engendered. Two broad approaches to the sociology of errors have emerged in the last 20 years. Firstly, is that based on "normal accidents theory". This theory was first proposed by Charles Perrow (1984). Perrow proposes that it is the nature of systems themselves that make them prone to error. A "normal accident" is defined as an interaction of multiple failures that are not in direct operational sequence. The elements of a normal accident are found where there is:

- A large number of components (parts, procedures, operators)
- Two or more failures among interacting components
- Tight coupling comprising
    - Very fast processes
    - Failed parts which cannot be isolated
    - No alternative method of maintaining production

Perrow attributes these characteristics (summarised as a combination of interactive complexity and tight coupling) to a number of high risk industries, including the nuclear industry, aircraft, air traffic control and shipping. Perrow considers that major accidents are inherent in these industries compared with more loosely coupled, linear industries. The recent poor record of the UK construction industry on fatal accidents gives support to the application of normal accidents theory to that industry and, depending on how the theory is interpreted, either to a fatalistic view that accidents are inevitable, or to the view that, as accidents are normal in construction, then exceptional organisational efforts will be needed to contain them. It is Perrow's view that error control cannot be left to operators and he gives considerable attention to the political element of errors within organisations:

> "we found rampant attribution of operator error to the neglect of errors by the Great Designers and the Centralised Managers
>
> .....the point of this book is to see these human systems, not as collections of individuals or representatives of ideologies. They are systems that elites have constructed, and thus can be changed or abandoned" (page 351)

Sagan (1993), in examining nuclear weapon accidents in the USA and Vaughan (1990) in examining the Challenger space shuttle disaster, follow Perrow in providing evidence for normal accidents theory. Although they refrain from proposing solutions, both also emphasise the political dimension of organisations, where accidents are covered up to protect senior managers, or misattributed to operatives. Vaughan proposes the interesting theory that a relatively close relationship between autonomous external regulators and the regulated companies may have predisposed the Challenger to failure. Accepting this view has considerable implications for the modern approach to health and safety regulation in construction, which, in many instances, emphasises co-operation rather than prosecution.

The second approach to the sociology of errors stems from a group of researchers at the University of California, Berkeley, USA, who have studied so called "High Reliability Organisations" in air traffic control, nuclear power generation and naval operations (Roberts 1993, Rochlin et al 1987, Rochlin 1993). These organisations have exemplary safety records and the researchers have isolated eleven distinguishing characteristics of their management (Rochlin 1993):

1) Errors are recognised as being omnipresent and eternal and vigilance the price of success
2) Sources of error are recognised as dynamic and thus monitoring mechanisms must be continually renewed/reinvigorated
3) The operating environment is considered a constant source of threat
4) No rationalising of the problem solving process into one best approach is possible or used.

5) Multiple simultaneous informal organisational structures exist
6) Anticipatory modes of dealing with problems are used.
7) Support is provided for organisational units searching for latent errors.
8) An unwillingness exists to "test the boundaries of reliability" (i.e. HROs do not use "trial and error" learning)
9) There are no "stopping rules" (i.e. rules limiting the extent of searching) in the search for self improvement
10) A tradition of adherence with formal rules (expressed as "going by the book")
11) Even when full analysis of errors is available, the organisation still perceives the need to search for error.

Although Rochlin does not indicate the method by which these characteristics can be engendered, Hirshorn (1993), also writing from an HRO perspective, provides interesting guidance. He stresses the role of leadership in high risk organisations by contrasting the concept of hierarchy with that of bureaucracy. A hierarchical form of organisation maintains and emphasises clear links of authority and responsibility from top to bottom, which allows the accurate allocation of risks between members. A bureaucratic organisation relies for functioning on detailed procedures and checks, a process which allows organisational leaders to avoid taking the risks of the enterprise. Bureaucratic control procedures invert authority by emphasising "rules rather than roles", but without a system for backing up action where gaps in the rules are found. Hirshorn sets out a four part model of effective organisation for high risk settings which includes:-

1) A hierarchical structure
2) Delegation which is broad and deep
3) Two classes of procedures
    a) Grounding procedures giving broad guidelines, which applies to a wide range of circumstances and is strictly applied.
    b) Detailed procedures where employees are free to vary precise steps as long as they fulfil intentions.
4) Emergency procedures to integrate (a) and (b)

In advocating a hierarchical form of structure, Hirschhorn makes the point that the hierarchical form, derived from the military and the contingencies of battle, remains a powerful social intervention for managing risk.

Although normal accidents and HRO theory start from contrasting assumptions regarding the nature of organisations, there are some points of correspondence. Both approaches acknowledge the role of senior managers in the conduct of organisations and the formation of organisational culture. Perrow emphasises the political element of organisational life and notes the power of controlling elites and Hirshorn similarly emphasises the need for acceptance of responsibility by senior managers and for a hierarchical managerial structure. There are interesting parallels with the literature on Total Quality Management. Both Oakland (1998) and Bell et al (1994) place responsibility for product or service quality in the hands of management and suggest that TQM starts "from the top" with "visible management commitment". At the same time, the TQM approach emphasises acceptance of personal responsibility for actions.

The importance of managerial roles is reflected in recent research on the influence of managerial factors on errors leading to construction defects (Atkinson 1999), where it was found that there was a significant association between the background, experience and training of project managers and the number of defects. This suggests that the personal qualities of managers are important in avoiding errors rather than the bureaucratic rules that they follow. The conclusion from both literature and research, therefore, is that responsibility for the control of errors (and consequently, safety) should be personal and placed at the very top of an organisation.

This conclusion provides support for recent legislative proposals in the UK to strengthen the law related to the responsibility of senior management for the incubation of accidents. Whilst it has long been possible to prosecute companies for breaches of regulations, it is difficult to indict individual managers for serious crimes, such as manslaughter, for two reasons. Firstly, manslaughter requires that intention be established and it is difficult to prove that an individual or collection of individuals actively intended an accident to happen. Secondly, most managerial actions are shared between a number of individuals and it is difficult to detect the "directing mind" responsible for the failure within an organisation. This difficulty has led the UK Government to consult on a new law of Corporate Killing, which would allow the prosecution (including the imprisonment) of senior managers without needing to show "intent", where gross negligence causes death or serious injury (Home Office 2000).

THE COSTS AND BENEFITS OF A LAW ON CORPORATE KILLING

Although the argument for the offence of Corporate Killing is usually based on moral justification, it is also necessary to support this change in the law on accident reduction grounds. To simply imprison senior managers, without considering the "deterrent" effect of the punishment could lead to charges of "scapegoating" - selecting a suitable individual to blame and exacting revenge. The literature cited above, emphasising the importance of senior management roles as a determinant of culture, provides one part of this support. Whether from a normal accidents, HRO, or TQM standpoint, senior managers are considered important in the overall direction of public or private organisations. A second part of this support relates to the economic benefits stemming from a change in the law. The effectiveness of the offence of Corporate Killing can be determined by using standard cost/benefit analysis. Provided an expected reduction in fatalities in construction is achieved, the deterrence is economically worthwhile if the cost of life saved is greater than the minimum level of punishment needed to achieve the reduction. Table III shows a simple cost benefit analysis taking into account the estimated cost of a one year custodial sentence (including the cost of immediate loss of salary and long term reductions in earnings by the indicted) compared with the value of a single life saved. A positive NPV is indicated except for the most senior managers of the largest UK companies. However, as the deterrent effect of imprisoning the latter is likely to be much greater than for managers of smaller companies, the impact of each sentence should lead to greater reductions in fatalities and, consequently, a positive NPV for even these scenarios.

Table III. Cost benefit analysis of one year imprisonment of a senior manager compared with the value of one life saved in consequence

Manager's Salary[1]		-50000.00	-100000.00	-200000.00	-473000.00
Future reduction in earnings[2]		20000.00	40000.00	60000.00	80000.00
Number of years[3]		20.00	20.00	20.00	20.00
Discount rate[4]	0.05				
NPV OF REDUCTION IN EARNINGS		-249244.21	-498488.41	-747732.62	-996976.83
Cost of incarceration[5]		-24357.00	-24357.00	-24357.00	-24357.00
NPV OF COST		-323601.21	-622845.41	-972089.62	-1494333.83
VALUE OF LIFE SAVED[6]		847580.00	847580.00	847580.00	847580.00
TOTAL NPV[7] OF ACTION		523978.79	224734.59	-124509.62	-646753.83

Notes to table

1) Managers salary based on typical range. Top salary (£473 000.00) based on median earnings of top 100 UK Director's earnings (Independent 2000)
2) Future reduction in earnings as a result of loss of position or reduced salary
3) Number of years estimated to retirement.
4) Current treasury long-term discount rate
5) Cost of incarceration (based on HMPS 1997)
6) Value of preventing one death at 1996 figures (DETR 1997)
7) "Net Present Value" of immediate and future costs and benefits

CONCLUSIONS

Despite a steady reduction in injury rates in the United Kingdom construction industry over the last two decades, recent worsening statistics indicate that a "plateau" of reduction has been reached. This suggests that the progressive introduction of bureaucratic management measures, including the CDM Regulations (HMSO 1994), has reached the limit of its effectiveness. If zero accidents are to remain the goal of construction professionals, then complimentary approaches need to be considered. One solution is to promote the acceptance of personal responsibility by senior managers for their actions in influencing the culture of their organisations. Recent proposals for an offence of Corporate Killing have been made and a review of the literature covering human error, particularly related to sociology and quality management, indicates that fixing responsibility for actions with senior managers would be effective. This would encourage senior management to adopt a safety conscious role and a pro-active safety culture. Research shows that culture is "determined from the top". Therefore, improvements in safety throughout an organisation should flow from the new (legislatively backed) responsibilities of managers.

Although quantifying death in monetary terms cannot fully reflect the value of loss of life, cost/benefit analysis also shows that legislating against Corporate Killing is likely to be cost effective. Thus, leaving aside the moral arguments for fixing liability where it belongs, provided the proposal acts as a minimal deterrent, it will also be economically sound.

REFERENCES

[1] ACSNI (1993) Advisory Committee on the Safety of Nuclear Installations - Study Group on Human Factors Third Report: Organising for Safety. HMSO

[2] Association of Personal Injury Lawyers (APIL) (2000) Reforming the Law on Involuntary Manslaughter - A Response. http://www.apil.com/consultation.asp

[3] Atkinson A R (1999) The Role of Human Error in Construction Defects, Structural Survey 17/4, 231-236, MCB University Press, Bradford UK

[4] Bea R G (1994) The Role of Human Error in Design, Construction and Reliability of Marine Structures, US Ship Structure Committee (National Technical Information Service, USA)

[5] Bell D, McBride P, Wilson G (1994) Managing Quality, Institute of Management Foundation, Butterworth-Heinmann

[6] Blockley D I (Ed) (1992) Engineering Safety, McGraw Hill.

[7] Department of the Environment, Transport and the Regions (DETR) (1997) - Highways Economics Note No. 1, Appendix 1 - The Valuation of the Benefits of Prevention of Road Accidents And Casualties in 1996, Stationery Office. http://www.detr.gov.uk/

[8] Embrey D E (1992) Incorporating management and organisational factors into probabilistic safety assessment. Reliability Engineering and System Safety 38, pages 199-208

[9] European Economic Community (EEC) (1992) European Directive 92/57/EEC Implementation of minimum safety and health requirements at temporary or mobile construction sites. EEC

[10] Fortune J (1984) Complexity, Management and Change: Applying a Systems Approach, Block 2, A Systems Approach to Failures, Unit 7, Studying Systems Failures. Open University Technology Course T301, Open University

[11] Fortune J and Peters G (1995) Learning from Failure: The Systems Approach, Wiley

[12] Harrison P I (1992) Organisational, Management and Human Factors in Quantified Risk Assessment. Report Nr2. HSE Contract Research Report Nr34/1992. HMSO 1992

[13] Health and Safety Commission (HSC) (1993) Annual Report, HMSO

[14] Health and Safety Commission (HSC) (2000) Annual Report, Stationery Office

[15] Health and Safety Executive (HSE) (1976) Final Report of the Advisory Committee on Falsework (the Bragg Report). HMSO

[16] Health and Safety Executive (HSE) (2000A) Rates of Workplace Injury: Europe and the USA. http://www.hse.gov.uk/hsestats/eurocomp.pdf

[17] Health and Safety Executive (HSE) (2000B) Construction health and safety for the new Millennium, HSE Contract Research Report 313/2000, Stationery Office

[18] Health and Safety Executive (HSE) (2001) Fatal injuries, 9 months statistics for 2000/01. National Statistics. http://www.hse.gov.uk/ops_unit/fatal00.htm

[19] Her Majesty's Prisons Service (HMPS) (1997) Next Steps Report, Stationery Office. http://www.official-documents.co.uk/document/cm38/3889/3889.htm

may be stacked vertically in a common trench, whereas multiple lines could be grouped in common utility tunnels called utilidors.

Challenges in Locating Utilities

Underground utilities at shallow depths can be located with relative ease using inexpensive equipment; while other utilities, especially smaller non-conducting utilities at greater depths, are extremely difficult to locate. Additionally, the complex signal records produced by some types of current locating equipment requires expert interpretation, which raises costs, and makes underground utility location an art as well as a science. Another challenge is that informed guessing about the location of utility lines is not good enough—for some utilities, hits cause interruptions to daily life and commerce; for others hits can cause physical danger to workers, bystanders, and nearby buildings (Carver 1998). All hits result in expense that is borne by a combination of the contractor, locating company, utility providers, insurance companies, and the affected public and business owners.

Costs of Utility Mislocates

The costs of utility damages are very significant and on the rise. The chances of property loss, injury, and even death are real in construction due to the obvious danger involved when striking gas or high-pressure petroleum lines. These dangers and the resulting incidents are more real than most people are aware. Bernold (1994) reported that excavating equipment hitting buried utility lines causes an average of one death per day in the United States. A sampling of serious incidents since January 2001 (Underground Focus 2001) listed here, indicates the impact of "mislocates" on human life and property:

- In Longmont, Colorado, three workers were injured in a gas explosion after they damaged a gas main while installing a sidewalk and bike trail. They suffered burns to their hands and faces. The workers told authorities the line had been marked, but was not buried as deeply as they had expected.
- In Turbridge, Massachusetts, police evacuated some one hundred people from a shopping complex after gas escaping from a damaged propane pipe exploded and sent flames 20 feet into the air. No injuries or property damage were reported. A worker digging a trench for a sewer installation damaged the line.
- In Berkeley, California, several businesses including a medical clinic were evacuated, and roads were closed after a city crew sliced through a 4-inch steel gas line. The crew was using a backhoe to install a street light at the time of the accident.

Not all damage to utilities is reported or is immediately detected. This makes assigning responsibility for damage costs difficult. This lack of report or detection may also cause later service problems that are difficult to trace, or cause unexpected severe safety consequences.

ROLE OF SUBSURFACE UTILITY ENGINEERING IN CONSTRUCTION PROJECT DEVELOPMENT

Typically, the design of a project is based on existing records that frequently are incorrect, incomplete, out of date, or inadequate for actual design and construction purposes. Some as-builts may be correct, but others are not correct due to human error during the recordkeeping.

One example of error includes the records created by decades of multiple utility owners installing underground structures at the same site, who for the most part never placed the records in a single central file, or the records are incomplete or are now lost. The references on the record drawings are lost and cannot be recreated.

Subsurface Utility Engineering (SUE) is an emerging solution that addresses accurate location of underground structures. It is the *"convergence of new site characterization and data-processing technologies that allows for the cost-effective collection, depiction, and management of existing utility information"* (Lew 2000).

Quality Levels

In order to understand the concept of SUE, it is first necessary to understand the quality levels established for subsurface information. The normally accepted definitions are as follows:

Quality Level "D" (or QL "D") is the most basic level of subsurface locating information. All QL "D" information is derived from a review of available existing records and utility as-built records. The application of this level is for planning purposes such as route selection and utility relocation costs. Quality level "D" information is limited in terms of the detail, accuracy, and comprehensiveness required to eliminate the risks and dangers of conflict with underground structures.

Quality Level "C" (or QL "C") information is the most common type used for design purposes. This level involves adding to and adjusting Quality Level "D" as-built information with an aboveground inventory of all visible features and evidences of utilities or foundations. Level "C" information is still not accurate enough to prevent conflicts. Studies have shown that with accepted tolerance standards of two feet or less, there is still a 15 to 30 percent error and omission rate.

Quality Level "B" (or QL "B") involves the actual use of technology that supplements Quality Level "D," as-built information, with "designating." Designating requires the use of surface geophysical techniques and methods to determine the existence and horizontal location, in two dimensions, of underground structures and utility features. This designating, or horizontal mapping information, permits sound decisions to be made during the design phase of a project on the placement of foundation footings, drainage systems, and any subsurface feature that conflicts with existing utilities and underground structures. Information in this level should not be used for vertical design basis or when close or minimum horizontal tolerances are required.

Quality level "A" (or QL "A") represents the highest accuracy level of presenting subsurface features by adding actual "locating" to Quality Level "B" information. Information can now be mapped horizontally and vertically in three dimensions. Locations are determined by nondestructive excavation methods at critical conflict points to expose the underground features. Exact determinations of horizontal and vertical positions are now made in three dimensions. The resulting highly accurate information is used to design the project to avoid most underground conflicts, thus avoiding utility line relocation or nearby excavation, providing condition assessment, construction, and maintenance information.

GEOPHYSICAL METHODS USED FOR LOCATING SUBSURFACE FEATURES

Traditional methods used by utility owners are to mark locations for contractors at the time of construction. These methods will remain in use, however, they do not provide sufficient damage prevention. Therefore, for both older and new sites, it is paramount that one also use one or more of the many new surface geophysical methods and equipment that are now available to the SUE practitioner to locate underground features. The geophysical methods shown in Table I are typically employed with Subsurface Utility Engineering.

Table I: Surface geophysical methods available for subsurface feature locations (Anspach 1996)

Title of Method	Description of Method
Radiofrequency Electromagnetics ELF, VLF, LF ranges	Inexpensive and highly useful for metallic lines, or accessible utilities that can have conductors or transmitters inserted into them.
Magnetics - Flux gate	Inexpensive and most useful for utility lines and appurtenances that exhibit a strong magnetic field at ground surface.
Elastic wave introduction into a non-compressible fluid	Inexpensive and moderately useful for water lines with sufficient access points (typically fire hydrants) and low ambient noise.
Terrain Conductivity	Moderately inexpensive and useful in non-utility congested areas, or areas of high ambient conductivity. Most useful in the detection of tanks and drums.
Impulse Radar (Ground Penetrating Radar)	Moderately expensive and highly interpretative. Useless in areas of high conductivity such as marine clays, or for small targets like small diameter lines.
Seismic Reflection and Refraction	Expensive and highly interpretative. Its usefulness under field conditions is extremely limited due to signal/noise ratio problems.
Thermal Imagery	Moderately expensive and interpretative. It is sometimes useful for poorly insulated steam systems or other high heat-flux systems.
Radioisotope Tracing	Moderately inexpensive to highly expensive. Useful for utilities already impregnated with radioactive isotopes.
Microgravitational	Expensive. This method is limited to identifying utilities of large differential in mass from their surrounding environment.

The main components of SUE are:

Designation – Designation is the use of geophysical investigating techniques and methods (as shown in Table I) to determine the existence and horizontal position of underground utilities and structures. A designation may possibly indicate the existence of two or more utility lines, thus requiring location to determine exactly what is there.

Location – Location is the use of nondestructive digging equipment at critical points along a subsurface project's path or location to determine the exact and precise horizontal and vertical position of buried utilities and other subsurface objects.

Data Management – Data Management is the use of the above Designation and Location information to allow designers and engineers to examine project options and plan ahead to eliminate conflicts before they occur. The information can be obtained by conducting surface geophysical surveys, and then entering the information into a computer-based data management system.

COSTS AND BENEFITS OF SUE

In a Federal Highway Administration (FHWA) sponsored research project on SUE, the costs of obtaining Quality Level "B" (QL B) and Quality Level "A" (QL A) data on 71 projects (selected randomly from a list of projects that utilized SUE) were less than 0.5% of the total construction costs; and resulted in a construction savings of 1.9% over traditional Quality Level C (QL C) and/or Quality Level D (QL D) data. A savings of $4.62 for every $ 1.00 spent on SUE was quantified from these 71 projects (Lew 2000) The projects included a mix of interstate, arterial, and collector roads in urban, suburban, and rural settings.

A study by the National Transportation Safety Board (NTSB) determined that excavation construction activities are the largest cause of pipeline accidents. The Safety Board concluded that providing SUE information to planners can reduce conflicts between underground facilities and excavators. (National Transportation Safety Board 1997)

SUE reduces utility line relocations, unexpected utility conflicts, cut utility lines, and conflicts with abandoned buried tanks; and increases the accuracy of environmental site assessment. These benefits combined with subsequent reduction in bid prices, reduction of construction delays, reduced contractor claims, and lower redesign costs may result in higher savings on a typical project. Based on a national highway construction/rehabilitation expenditure of $ 51 billion (in 1998), the use of SUE in a systematic manner can result in a minimum national savings of approximately $ 1 billion per year.

SAVINGS IN ACCIDENT REDUCTION

Accident reduction in utility line cuts could result in the reduction of general liability insurance premiums and worker's compensation premiums, which were considered to be SUE savings. Determination of these savings, which approaches 0.5 percent of project cost, is shown in Table II. General liability coverage provides protection against accidents like cutting utility lines and causing harm to the general public. Considerable risk exists in excavation work conducted in the vicinity of buried utility lines. Gas lines are cut or damaged resulting in fatal accidents, and the victims are frequently from the general public. In Table II, the amount of the general liability premium is based on the need to pay all accident claims.

Table II: Cost savings due to reduction in accidents (Lew 2000)

ITEM	OHIO	TEXAS
I. GENERAL LIABILITY SAVINGS (BASED ON NEED TO PAY ALL ACCIDENT CLAIMS)		
Manual Rating	Manual Rating is $35.70 per $1,000 of payroll.	Manual Rating is $69.00 per $1,000 of payroll.
Cost Savings	Urban: 0.002142 x project cost. Rural: 0.001428 x project cost.	Urban: 0.00414 x project cost. Rural: 0.00276 x project cost.
II. Worker's Compensation Premium Savings through reduction in the experience modication rating (EMR) (Based on 0.05 reduction in EMR when SUE is used)		
Manual saving factors	WC cost Ohio: $7.67/$100 of payroll	WC cost Texas: $11.25/$100 of payroll
WC, Cost Savings	Urban: 0.00075 x Project Cost Rural: 0.0005 x Project Cost	Urban: 0.001335 x Project Cost Rural: 0.00089 x Project Cost

CONCLUSIONS

Subsurface utility engineering can assist in locating subsurface lines and hazards that can lead to major highway and/or utility shutdowns and construction accidents. This significantly reduces:

- Delays caused by redesign when construction cannot follow the original design due to utility conflicts.
- Delays to the contractor during highway construction caused by cutting, damaging, or discovering utility lines that were not known to be there.
- Subsequent contractor claims for delays resulting from unexpected encounters with utilities.

If accurate utility information is available to highway designers early in project development, then highway designers can design around many potential conflicts, thereby avoiding unnecessary utility relocations. This also reduces delays to the project caused by waiting for utility work to be completed. Safety is enhanced. When excavation or grading work can be shifted away from existing utilities, there is less possibility of damage to a utility that might result in personal injury, property damage, and releases of product into the environment.

THE PATH AHEAD: RESEARCH ACTIVITIES IN UTILITY DETECTION AND LOCATION

Since January 2001, the authors have been involved in an Indiana Department of Transportation - Joint Transportation Research Program (INDOT/JTRP) project that investigates the use of locating and imaging technologies for highway projects. Electromagnetics, magnetics, ground penetrating radar, seismic reflection and refraction, thermal imagery, and variations in gravitation fields are selected as imaging technologies that have potential for being applied in locating underground utilities. Data will be collected from candidate projects for each of the technologies for identification of:

- Range of applications;
- Basis for selection of imaging techniques;
- Site specific factors that have to be considered;
- Relative cost information including direct and indirect costs;
- Department of Transportation concerns and environmental issues; and
- Current DOT practices (from across the country) with respect to the use of these specific technologies.

An evaluation will be performed to determine the applicability of these technologies in urban right-of-way settings, their ability to operate through asphalt or reinforced concrete road pavements, tolerance for interference from metallic objects nearby, compactness of the technology (i.e., the footprint of the imaging device must be sufficiently small to occupy a small area of the street to minimize interference with traffic flows on major routes), portability and ruggedness for field use (effective under differing temperature and moisture conditions, able to operate in urban environmental conditions), applicability for different site conditions, ability to withstand long-term use in field conditions (including immersion in water and potentially corrosive fluids/gases that may be present), and level of training required for effective use in the field and for analysis of data.

The study is expected to be completed by December 2002.

ACKNOWLEDGEMENTS

The first author acknowledges with gratitude the support provided by the National Science Foundation (NSF) through grants CMS-9800204 and CMS-9973509, in enabling the study of underground infrastructure systems and their detection, assessment and management.

REFERENCES

[1] Anspach, J. H. (1996). Subsurface Utility engineering: Utility detection methods and applications. Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Environmental and Engineering Geophysical Society, Keystone, CO, USA, SAGEEP '96, 443-450.

[2] ASCE/ANSI. (2000 in preparation). Standard guidelines for the collection and depiction of existing subsurface utility data.

[3] Bernold, L. (1994). In-House study for a consortium for safe excavation. Raleigh, NC, USA: Department of Civil Engineering, North Carolina State University.

[4] Carver, C. (1998, January/February). Examine hidden costs of utility hits when allocating damage prevention dollars. Underground Focus Magazine.

[5] Purdue University / Federal Highway Administration. (2000). Cost savings on highway projects utilizing subsurface utility engineering. (Research Report Publication No. FHWA–IF-00-014). Washington, DC, USA: Lew, J. J.

[6] Moyer, P. D. and Noone, J. (1999). Use of Subsurface Utility Engineering techniques to access existing buried pipeline condition. Proceedings of the Pipeline Safety Reliability and Rehabilitation Conference, American Society of Civil Engineers, New York, NY, USA, September 1999, 205-218.

[7] National Transportation Safety Board. (1997). Safety Study: Protecting public safety through excavation damage prevention. Washington, DC: National Technical

Information Service. (NTIS Publication No. NTSB/SS-97/01, PB97-917003, Notation 6931).

[8] Sterling, R. (1999). State of need: Utility location technologies. Ruston, LA, USA: Louisiana Tech University, Trenchless Technology Center.

[9] Underground Focus Magazine Online. (Unknown revision date). [On-Line]. Available at: http://www.underspace.com/

[10] U.S. Department of Transportation, Federal Highway Administration, Office of Engineering. (March 1998). Program guide utility adjustments and accommodation on federal-aid highway projects. (Publication No. FHWA-PD-98-013). Washington, DC, USA

ECONOMIC IMPLICATIONS DERIVED FROM ACCIDENTS IN CONSTRUCTION

M. Casals, N. Forcada, F. Peñaranda, X. Roca
Dept. d'Enginyeria de la Construcció, Universitat Politècnica de Catalunya (Spain).
fernando.penaranda@upc.es

Every accident that occurs in a construction site, carrying injuries or not to the workers brings upon economic burdens. The study, determination and knowledge of these, will enable the application of techniques to avoid deviations of the companies profits. An approach to safety cost management is to integrate safety planning in the design phase, as well as, motivation and training as part of the safety costs. This can produce greater cost at the beginning due to more time dedicated to plan safety measures and/or implementing motivational programs, but once in the execution phase the rewards are visible and tangible.

This paper will deal with the conceptual implications of these procedures in order to achieve a localized scope of accident control and cost management in the Spanish environment. Key issues will be direct and indirect cost, responsibilities to be held upon accident occurrences, legal and penal implications, etc.

Keywords: Project safety, Safety management on site, Safety costs management, legal responsibilities.

INTRODUCTION

When a worker is injured because of a work related accident, and he/she is unable to continue working, a process starts with the treatment, healing, convalescence and re-incorporation or not to the work place, all this depends on the consequences of the injuries suffered.

These injuries, even if they are classified and depending on which classification the accident falls in, economic consequences will be more or less grave, in terms of money.

The authors think that this, while it is an important matter and special attention has to be put on it, there are conceptual implications that need to be clear in order to achieve a sound Safety Cost Management when in charge of a contractor firm.

COST BALANCE

Safety Cost Management can be divided in two types of costs from the prevention point if view: **safety costs** and **non-safety costs**.

A common definition for **safety costs** is all the time and resources spent in planning safety prevention and control once on site; and in order to achieve a prosper and profitable Safety Management System some of these costs have to be included in the design phase of the project, even though there are some that can be attributed as fixed safety costs, because they form part of a fixed preventive structure of the company. Three groups of costs can be identified in safety costs:

8) Fixed preventive structure of the company

- Training and education. Including educational courses or programs.
- Motivational campaigns.
- Personnel management, as instructors and other support personnel.
- ...

9) Design phase costs

- Safety coordinator in the design phase (fees), in charge of the design aspects to take into account, once in the execution phase.
- Future maintenance preventive measures, such as anchorage points on the roof for maintenance of equipment, space for a future elevator in case of a future vertical growth, etc.
- Materials and time spent in designing safety on site
- ...

10) Execution phase costs

- Preventive measures. Collective and personal protective equipment, organizational measures to be adopted once on site, etc.
- Safety coordinator on site (fees), to control and manage the safety aspects of the construction, etc.
- Over cost in personnel management, for controlling and coordinating the logistics of the management system.
- ...

For **non-safety costs** the traditional definition is the cost of tending and correcting an accident, which is possible to divide in two groups:

1) Direct costs

- Salary compensations to the victim, depending on the graveness of the accident and injuries suffered.
- Medical expenses, which cover from the instant the worker enters the hospital until he/she is released.
- Transportation costs, to any place he/she needs to go to tend his/hers injuries.
- ...

2) Indirect costs

- Salary compensations to other workers, for attending the accident and their loss of productivity.
- Material and equipment damage due to the accident.
- Costs endured by the worker, as anguish and pain, or family problems.
- Costs endured by the company, as insurance policies over cost.
- Substitution of the worker and training of new personnel.
- ...

A conclusion that can be obtained from these definitions is that one the accident has occurred the prevention concept is placed on a second stage, centring all of the companies effort on the accident at hand as well as a mayor part of its resources.

The next step towards the knowledge of efficient and effective Safety Cost Management is to balance, the implications of safety costs and non-safety costs in the overall situation, obtaining the total cost of the accident.

COST MAP

In order to get the full picture of what happens in Safety Cost Management, all costs involved have to be clear and understandable.

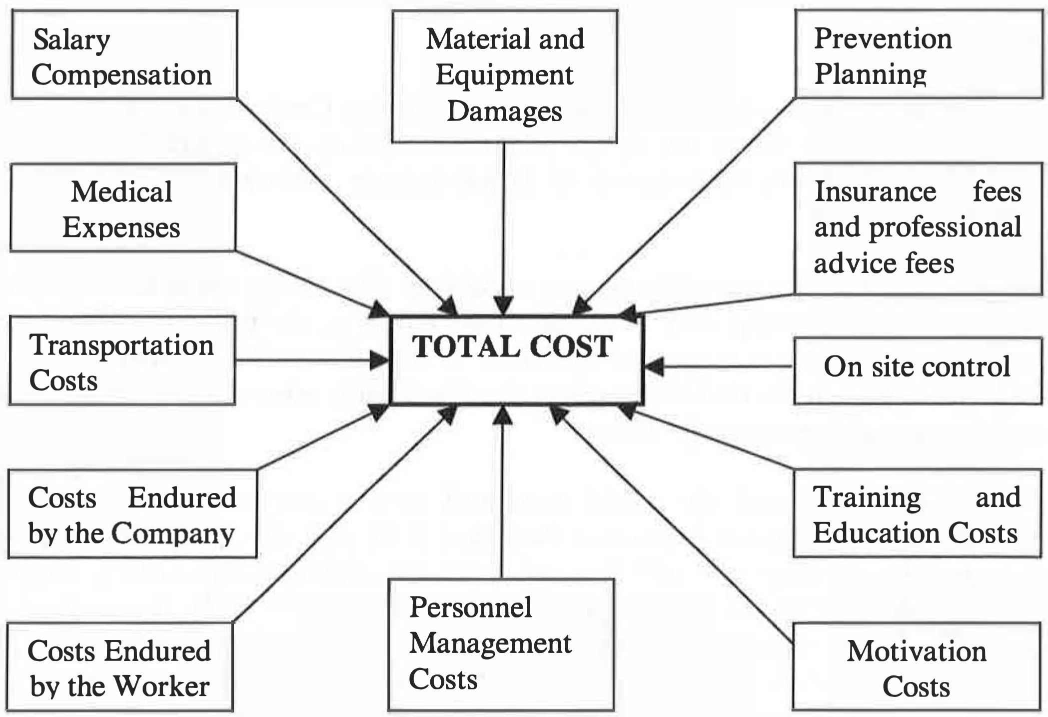


Figure 1. Cost Map.

Indirect and direct non-safety costs and safety costs come together to form the total cost of the accident, if it happens.

How do these costs combine themselves, is the objective of this paper, trying to imagine different scenarios of how a contractor might be affected depending, on their initial situation regarding safety management, and how are these costs quantified when adding up the total cost of an accident or trying to get the overall picture of safety cost management. Examples of these can be:

- Motivational costs are more of a midterm investment, so can a proportion be added when summing up the total cost of the accident? And can the education and training of the workers lower non-safety costs?

- Assigning economic value to prevention planning, since how much time is enough to prevent a possible accident? Does it depend of the complexity of the job at hand? Or can an average of the time spent in designing, can be assigned to the thinking process of prevention planning?

All these questions have their answer if the company prepares itself for a detailed and well-organized Safety Management System, preparing documentation, reports, registries, assigning responsibilities, and keeping track of the important aspects of Safety Cost Management.

WHEN TO ACT?

In order to have a clear picture of what happens in Safety Costs Management a careful study of the involved costs during the design phase is necessary, this to say that if a company is willing to include Safety Management in its management system, costs are a very important matter to take care of.

For a company that has a traditional way of dealing with safety, implementing safety in the design phase and training and motivation can appear as an increase in their direct cost structure, but the next few graphs will show different scenarios, demonstrating that even though this is true in the first stages of the implementation process, after some time the costs might decrease and/or tend to level out.

In the company, although the initial costs will tend to increase in the beginning of the implementation, the logical channel of thought will be that once the workers are motivated and trained the accident cost will decrease since less accidents will actually happen. In the following figure we see the non-safety costs represented as well as the motivational cost over time, and how this motivational costs can cause an effect of lowering the non-safety costs after a response time, this can be attributed to the learning curve of the workers.

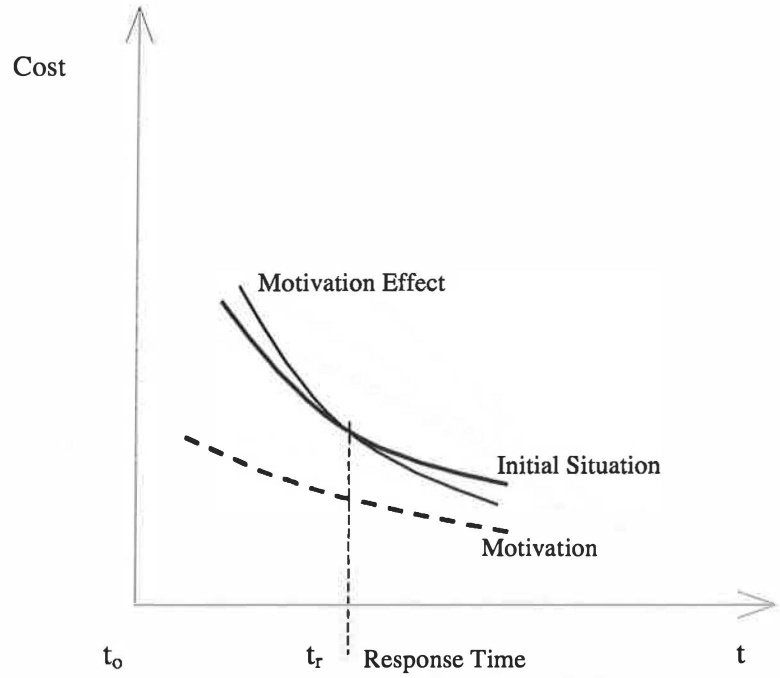


Figure 2. Non-safety costs, with a motivation effect.

In Figure 3, also represented over time, four different functions are shown of how the execution direct costs may vary.

The traditional cost structure a company would have will be the execution direct costs without the design phase costs, represented in the first curve from the top down. When the company is actually on site, and design phase safety cost are implemented, execution costs will be less since some of the logistics and setting up of the safety management on site has already been done. The second curve will be the result of having the design phase costs combined in the execution direct costs, thus, the decrease in the absolute values of the curve, respond to prevention planning.

Training and motivation implementation in the company, as well as in Figure 2 there is a response time between the implementation and the time when the results of the decrease in costs is tangible. The third curve represents the effect of the motivation and training of the workers when implemented. The fourth and final curve is the design cost curve, which is logically lower than the other three, since probably the absolute value of these costs is less than the execution costs because of the activities and materials involved in this phase.

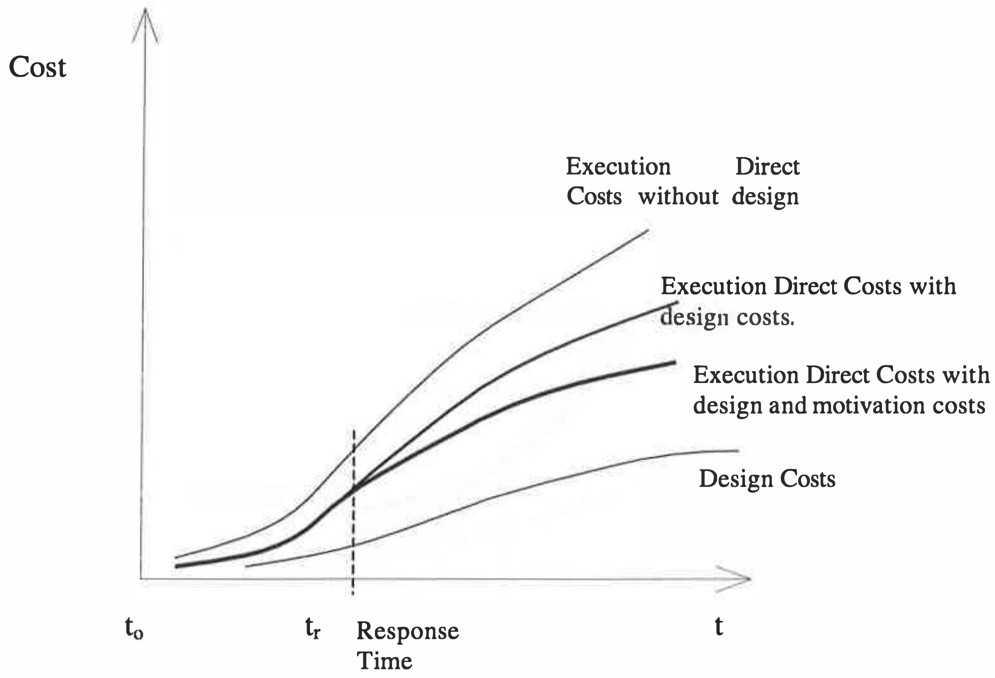


Figure 3. Execution Direct Costs.

A characteristic of these four curves is, that after a period of time, probably the rate of cost variance will decrease, since the company would be able to amortize the cost of implementing these kinds of practices in their company's daily activities.

After the previous analysis of safety and non-safety costs, and trying to reflect this behavior in the level of safety achieved in a company after the implementation of safety in the design phase and training and motivation, its is proposed that safety over time will tend to increase as a direct function of time S=f (t), and even though this relationship is not clear regarding its rate of increase what is clear is that as time goes by safety levels will be higher. Figure 4 represents this.

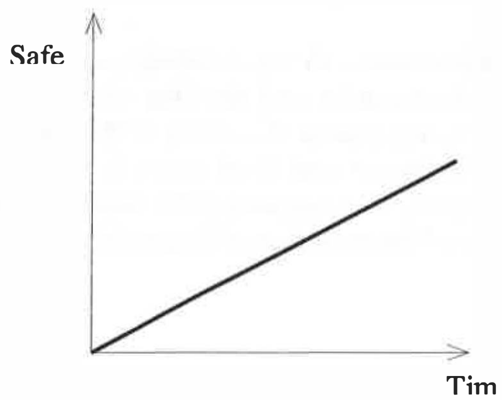


Figure 4. Safety as a function of time.

DISSCUSION

Having said the above, a company's performance regarding its Safety Management System can be explained in terms of cost and levels of safety, as functions of the company's initial situation when implementing these changes in their cost structure, for a company that has a high level of non-safety costs will probably have a higher rate of benefits regarding safety than a company that has been concerned in reducing its non-safety costs.

Examples of these are shown in the next graphs, as well as the discussion of the limits of this situation in a company.

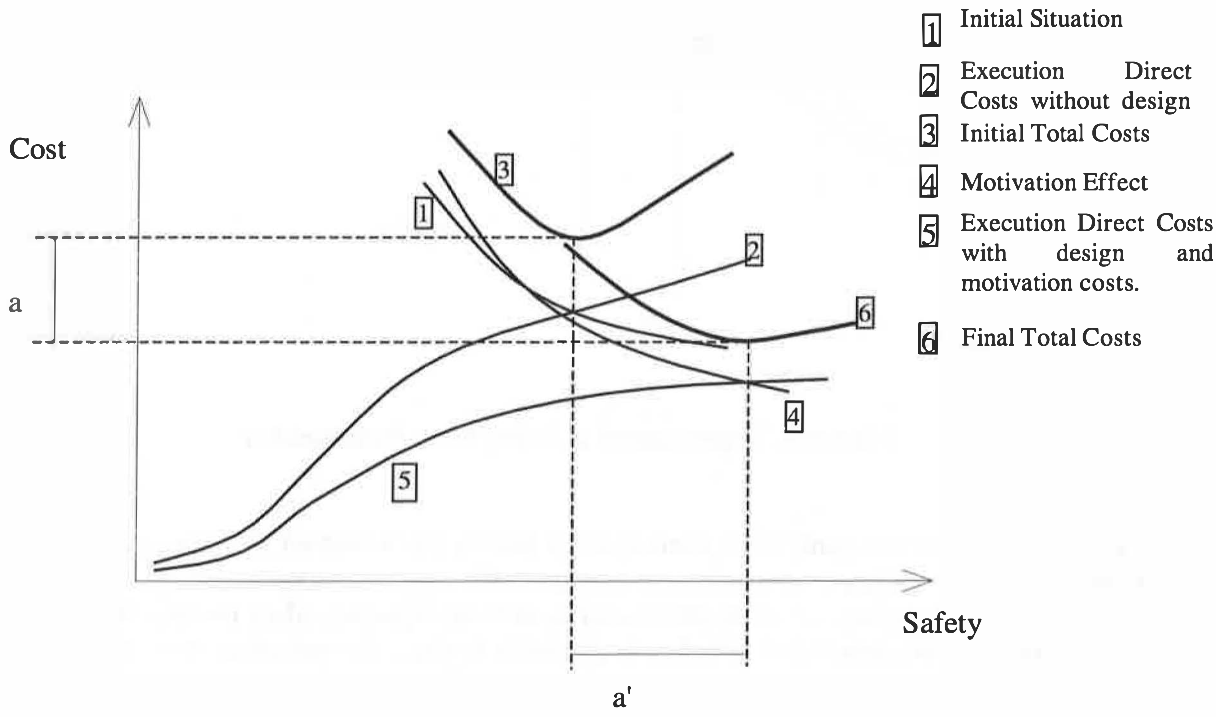


Figure 5. Poor safety cost management.

If a company has a deficient non-safety cost management situation, the above graph shows what could be happen if prevention planning safety costs are included in the design phase.

The difference between the final and initial total costs in terms of cost and safety, have a significant appeal to the company's management, and an example of this could be a company that has X number of accidents per year and by implementing these changes reduces that number of accidents in half. This 50% improvement also comes with a decrease in the minimum total cost, so to the company is not only appealing but also profitable.

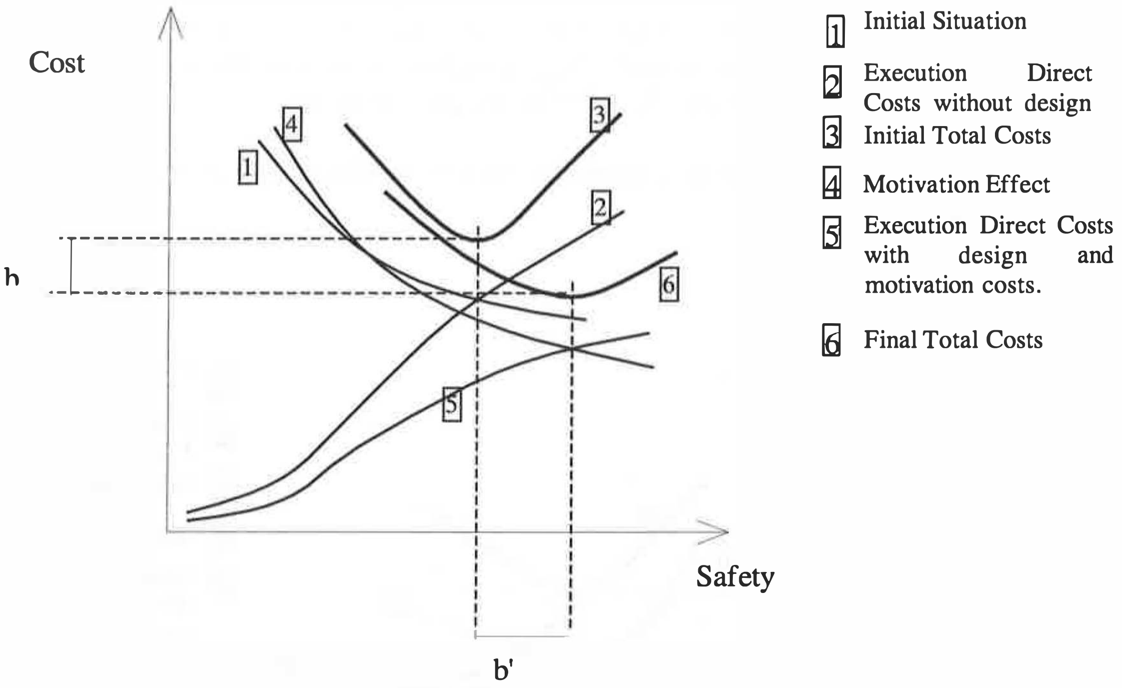


Figure 6. Improvement in Safety Cost Management

If we take the same company after some time of having implemented the changes, or another company that has a better management structure, the rate of improvement, while it's still beneficial to the company is not as substantial as the one experienced on the first instance and even though the absolute level of safety is probably higher, the reduction in overall costs is lower.

Taking the same example described before the company could go from the X/2 number of accidents to zero accidents having the same 50% improvement, but with less cost reduction. If we put these ideas in math terms the expression a/a'>>b/b', would be valid.

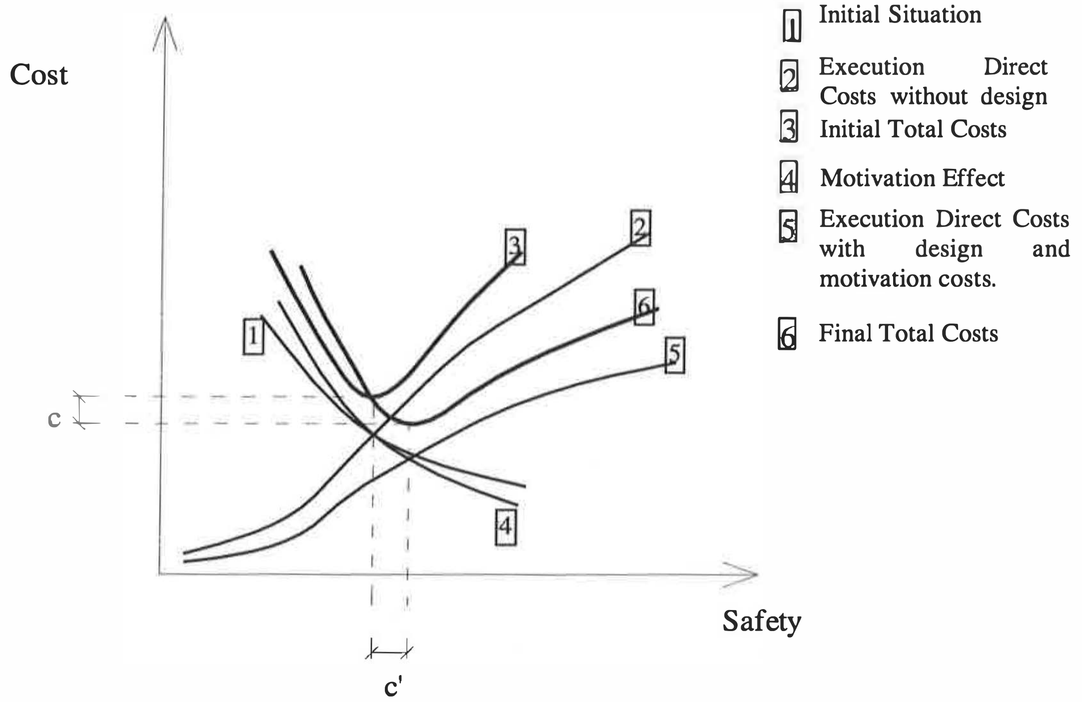


Figure 7. Good Safety Cost Management.

In this final graph the idea behind it, is to show how over time the effect described above continues to become more and more serious, each time gaining less benefit in relative terms with out improving in safety, until getting to a point where a company can be accident free for two years for example and spending a constant amount of money in securing this condition.

Analyzing the idea above described, some important concepts are detached, like, is it possible to achieve perfect safety with minimum costs? Is there a limit to this situation, or there would be a time when there is no possible improvement in costs? We think further study should be made in this area, in order to clarify the long-term effects of implementing safety costs in the design phase, as well as, training and motivation in the company's Safety Management System.

It has been shown that the inclusion of safety costs of the design phase tends to bring the optimum cost down at a higher level of safety. But it is also shown how over time the relative benefits in terms of money decrease if the company continues to implement these changes. Another conclusion is that motivation and training in a company can never decrease even if the company does not see the benefits instantly.

REFERENCES:

[1] Rodriguez Muñoz, Manuel (2000) Estudio comparativo de los sistemas de evaluación de riesgos laborales en la construcción. 119-139, Barcelona, Spain.

[2] Hinze J., Wilson G., (2000) Moving toward a Zero Injury Objective. JCEM, Vol. 126, 339

COST AND BENEFIT IMPLICATIONS AND STRATEGY FOR ADDRESSING OCCUPATIONAL HEALTH IN CONSTRUCTION

Alistair G.F. Gibb, Roger A. Haslam, Diane.E. Gyi
Department of Civil and Building Engineering, Loughborough University (UK)
A.G.Gibb@Lboro.ac.uk

Ill-health is a major cause for concern in the construction industry throughout the world. However, it is only just beginning to be taken seriously in a few countries. This is occurring generally the more developed countries where public opinion is becoming intolerant of the negative long-term effects of workplace ill-health. This paper introduces some of the cost and benefit implications of occupational health and ill-health in construction and proposes a strategy for addressing the key problems. The text has been drawn mainly from two documents namely the European Construction Institute's ECI guide to managing health in construction (Gibb et al 1999) and a proposal by the authors to the UK government for a partnership in construction health (APaCHe, unpublished).

ILL-HEALTH IS A MAJOR PROBLEM FOR CONSTRUCTION

The World Health Organisation defines health as a "state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (WHO, 1998). Furthermore, the authors argue that this concept of health can be extended to apply to organisations as well as individuals. Healthy organisations operate to meet their objectives efficiently, providing healthy, fulfilling employment for their workers. In promoting healthy individuals and organisations, prevention is considerably more effective than cure. Truly effective prevention requires a holistic, whole-system, complete life-cycle approach. This needs to recognise and address the complex influences arising from individual and collective attitudes and actions.

In the past less effort has been directed towards health matters in the construction industry in favour of the more immediate, high profile (and perhaps more easily solvable) problem of safety. The phrase health and safety is often used to represent only safety. Few health and safety managers, supervisors or inspectors have anything more that the most rudimentary knowledge of occupational health matters.

Nevertheless, ill-health continues to disable and kill large numbers of construction workers throughout the world. In fact, the delay in the effects becoming obvious is one of the main reasons why the subject should be taken seriously.

Every year many thousands of construction workers suffer from ill health as a result of their work. According to the UK's 1995 Self-reported Work-related Illness Survey, an estimated 134,000 people having worked in construction in the previous 12 months reported a health problem caused by their work, resulting in an estimated 1.2 million days lost in a work-force of 1.5 million. The self-reported work-related illness prevalence rate was 6.8% in the construction sector compared with an average of 4.7% for all industry. The most significant of the wide range of health problems facing construction were asbestos related disease (about 700 deaths annually); musculoskeletal disorders (96,000 cases); respiratory disease (15,000 cases); skin disease (6,000 cases); and noise induced hearing loss (5,000 cases). Recent research also indicates that construction workers are particularly at risk from hand-arm vibration. A feature of many of these conditions is a long latency period between exposure and onset of symptoms, leading to difficulties attributing ill health to its origin.

Construction organisations are aware of the ill health associated with their activities, but have difficulty managing it in an industry with a highly peripatetic workforce, little continuity of employment, many at least notionally self-employed workers, and short-term, rapidly changing workplaces.

Furthermore, there are other more general life-style-health issues for construction workers, often linked with the itinerant nature of their employment. Construction workers are also less likely to visit their GP ('family doctor'), with estimates that 80% have not even registered.

Staying for the moment with the UK, the Government estimates that, by the year 2020, asbestos-related diseases will kill up to 10 000 people each year (Croner 1998) and 36000 people suffer from 'vibration white finger' with over a million considered to be at risk (HSE 1998). UK and US construction workers have the third highest rate of skin disorders (Burkhart 1993) and cement is believed to cause up to 40% of all cases of occupational dermatitis in the UK (Beck, 1990).

The problem is no better elsewhere in Europe. For example, the 2000 largest enterprises in Portugal lost more than 7.7 million working days as a result of illness in 1993 representing 4.5% of all working days for these companies (Gründemann & van Vuuren, 1998). In Denmark, 20% of sickness absence among 15 to 66 year-olds is caused by the working environment (Gründemann & van Vuuren, 1998). In Germany, dermatitis is becoming the main reason for absence from work (Berger 1998).

There are variations in the way that health and safety are legislated for and controlled in different European States (European Commission 1995 & 1997). However, in general, health and safety are considered together, with health very much the poor relation.

THE COST OF WORKER ILL-HEALTH IS INCREASING

The real cost to industry due to ill-health in all countries is significant and includes:

- lost production
- insurance
- compensation
- recruitment
- re-training

In addition there are costs to society that include:

- social security

- health care
- early retirement

The costs to industry, workers, their families and the nation, of ill health arising from construction is difficult to quantify, but one recent estimate put the total cost in the UK at around £760 million (1267 million Euro) per annum (1995-96 figures).

Specific examples include the following:

- Absence from work through ill-health costs UK industry £12 billion (~20 billion Euro) a year (Confederation of British Industry, 1997).

- In 1993 German employers paid DM 60 billion (~30.5 billion Euro) for the social security insurance of their workers to cover the payments for absence from work (Gründemann & van Vuuren, 1998).

- In 1995, Belgium paid 93 billion BFR (~2.4 billion Euro) on sickness benefits and 21 billion BFR (~0.6 billion Euro) on benefits for work accidents and occupational diseases (Gründemann & van Vuuren, 1998).

- The cost of benefits for sickness absenteeism and disability in The Netherlands in 1993 was 35 billion NLG (~16.6 billion Euro) (Gründemann & van Vuuren, 1998).

- The socio-economic costs of work-related diseases and accidents in Denmark in 1992 were estimated at between 3 to 3.7 billion Euro, on a working population of 3 million persons. (Gründemann & van Vuuren, 1998)

- Prosecutions and litigious court actions on occupational health grounds are now commonplace in countries such as the US and are starting to be seen in Europe as well. The sums of money involved are becoming more and more significant. Musculoskeletal disorders due to poor training and ergonomic design are the leading source of compensation claims in the USA (Hunting 1994)

- A UK health authority has recently settled out of court by paying £70 000 (~117 000 Euro) compensation for an office worker who became unable to work due to an upper limb disorder caused by her work inputting computer data (Anon 1998a).

- British Coal was found liable for causing respiratory diseases in six former miners. Estimates of the liability in related cases fall between £50 million and £1 billion (~83 million Euro and 1.7 billion Euro). The judge considered that committed efforts by the employer to control dust should have occurred 20 years earlier (Anon 1998b).

- A UK damp-proofing operative won £76 000 (~127 000 Euro) following developing hand-arm vibration syndrome through prolonged use of heavy hammer action drills between 1972 and 1994 (Anon 1998c).

- £185 000 (~308 000 Euro) damages were awarded to the widow of a 54 year old man who died of mesothelioma following workplace exposure to asbestos (Anon 1997a).

- Dermatitis costs the US between $222 million (~222 million Euro) and $1 billion (~ 1 billion Euro) each year (Rosen & Freeman 1992).

EMPLOYERS AND MANAGERS HAVE A RESPONSIBILITY TO MANAGE HEALTH RISKS

Clients and contractors have a statutory and common law duty to develop health risk management systems, which should be based on full and careful appraisal of the health risks to which all their employees (including subcontracted workers) will be exposed. For example, a UK employer was fined because no advice or warnings were given despite the fact that the dangers were known about (Anon 1998c).

HEALTH MANAGEMENT IS NOT EASY

The main difficulties voiced by the industry regarding occupational health management include:

- Health is a complex issue
- Health traditionally has a low profile compared to safety
- Health management is associated with potentially large set-up costs
- Benefits are not immediate and are consequently difficult to demonstrate.
- The latent effect of illness is difficult to quantify
- Exposure to health risks can be multiple with changes in the nature and level
- Long term strategies are required
- The workforce is sizeable, temporary and mobile
- Many workers are not directly employed
- The workers are often not interested, perhaps due to possible loss of livelihood or the endemic 'macho culture' of construction workers
- There is a lack of health expertise within the industry

No one is claiming that these problems are non-existent, but the industry must rise above the excuses and grasp the opportunity to manage its way out of the mire.

A STRATEGIC APPROACH TO HEALTH MANAGEMENT WILL RESULT IN BENEFITS

The main aim of health management is to prevent ill health rather than to cure it. Effective, strategic management action by senior managers will reduce accidents and incidents leading to injury and ill-health. However, despite this knowledge, construction managers understand their role in safety and the prevention of injury, but are less clear regarding the prevention of ill-health (Gyi et al 1998). This 'reality-gap' must be acknowledged and eradicated. There is little guidance on health management in construction available, certainly in the UK. In fact, one of the only health management manuals is the ECI guide to managing health in construction (Gibb et al, 1999). The UK HSE have been planning to release a manual for some years but this has still not materialised.

Whilst these issues must be first addressed strategically at senior management level, they must also be worked out at the project-level. This is developed further in the ECI health manual (Gibb et al, 1999). Health protection is a line management responsibility with medical professionals and other experts assisting in the development and implementation of the health management programme. The need for and type of medical support on site also needs to be determined. An appropriate health risk management system can then be developed. It is the responsibility of client and contractor management to ensure that appropriate control measures are provided, and their effectiveness evaluated.

The Exploration & Production Forum (1993) advised that a successful health management system should cover three broad areas:
- Formulating policy and developing the organisation. This includes identifying health objectives and reviewing progress towards their achievement
- Planning, implementing and auditing of health activities and standards
- Performance measurement and reporting

They also advise that at least the following should be in place:
- Roles defined
- Resources allocated
- Means of achieving objectives specified
- Performance monitored
- Specific task targets and procedures defined
- Compliance checked

Health risk management is largely devoted to the identification of health hazards that could arise. The client or designer can undertake this assessment, commonly known at this stage of a project as 'Hazcon 1 ", but the client must take responsibility. The Hazcon approach is described in greater detail in the ECI SHE manual (ECI 1995). The following should be used to aid this assessment:
- Overall project method statement
- Experience gained from previous projects including close out reports
- Similar activities in relevant locations
- Health audits carried out on similar project
- General background information on planned areas of operation
- Environmental issues
- Major risk factors
- Substances already at site and those that will be taken to site
- Emergency response procedures
- Incident reporting procedures
- Published guidance by enforcing authorities

The checklist in Table I is a guide for broad coverage of items which could effect an employee's health.

Table I. Factors affecting workers health (Gibb et al, 1999)

Physical	**Chemical**	**Biological**	**Mechanical**	**Psycho-social**
noise	liquids	insects	posture	stress
vibration	dusts	fungi	movement	work pressure
ionising radiation	fumes	bacteria	repetitive tasks	monotony
non-ionising radiation	fibres	viruses		unsociable hours
heat and cold	mists			ergonomical
electricity	gases			
pressure	vapours			

CREATING HEALTHY CONSTRUCTION PRODUCTS AND PROCESSES

In the UK, the Health and Safety Executive (HSE) has been raising the profile of health in construction over recent months with publicity following the launch of their 'Backs for the Future' guidance and a conference in October 2000 entitled 'Tackling Health Risks in Construction'. Health and safety is increasingly seen by employers and employees as an issue to be addressed collaboratively, as exemplified by the trades union/ employers (TUC/CBI) Partnerships in Prevention programme. There are synergies to be developed from the emerging "people first economy" strategy developed by the Department for Trade and Industry (DTI, 2001), with Respect for People, Investors in People, the Learning and Skills Councils and the commitment to lifelong learning prominent among these. With health issues intrinsically linked to construction processes, techniques and technology, an industry/academia/government collaboration is much needed, providing the essential support required for real improvement to be achieved.

Health consequences arise from the construction process, with linkages between the way in which construction is undertaken and risks that arise. Choices are made about how to build, directly affecting the health of workers, for example decisions taken whether to fabricate on-site or to choose pre-assembly. Pre-assembly can bring benefits for both health and safety, but at present influences on health are not understood to a sufficient extent to be able to endorse the approach from a health point of view. More generally, the industry often uses the changing, ad-hoc nature of sites as an excuse not to plan and organise the workplace efficiently to the detriment of the health of operatives. An ongoing trend has been towards construction projects becoming more complex, with time and cost constraints more severe. Associated with this are increased reports of stress amongst construction personnel (Madine, 2000). Some organisations have started to address this, for example Haliburton's Stress Toolkit training pack.

With regard to technology and techniques, tools and equipment used in construction are frequently not designed with the health of users to the fore. Some leading organisations working with Loughborough University are already addressing some of the challenges in this respect. This includes projects improving PPE glove design to give enhanced grip and dexterity (making it more likely that the PPE will be used); piloting an innovative electric breaker tool, that will reduce levels of hand/arm vibration; and developing the design of seats for drivers of construction plant, many of whom spend their whole working day, including breaks, in the seats of their cabs, a significant risk factor for back pain.

DEVELOPING HEALTHY CONSTRUCTION ORGANISATIONS AND INDUSTRY

The ECI Health Management Manual argues that larger organisations are just beginning to take health issues seriously. However, many small to medium sized enterprises (SMEs) have traditionally not had the infrastructure, resources or awareness to address these matters. The ability to develop health-conscious organisations has been severely hampered by the sub-contract and sub-sub-contract culture in construction as well as recent 'right-sizing' exercises in many organisations. A significant opportunity exists for expertise and technology transfer, as well as a need for research to develop appropriate strategies and practices.

The UK's Construction Design & Management (CDM) regulations (derived from the EU Directive on Temporary and Mobile Construction Sites) impact on construction processes by seeking to eliminate hazards through the design process. However, there have been concerns about the effectiveness of the implementation of the legislation, in terms of the extent to which it has lead to health and safety hazards actually being addressed, particularly by the design professions. Furthermore, most of the evaluation to date has centred on safety aspects, neglecting the major issue of health. In addition, from a human factors perspective, design extends to include the design of the work place, tools and techniques as well as the finished building or structure. This goes beyond the conventional understanding of design implicit in CDM.

A major challenge for the UK construction sector is the current shortfall between the supply of qualified new recruits and demand from the industry. The growth rate of UK construction output is expected to vary from 2.2% to 3.5%, over the period 2001-2005, with 64,000 new recruits required each year. However, there has been a sharp decline in the proportion of younger workers in the industry, as well as an increase in those aged 45 and over which "is a major cause of concern" (DTI, 2000). In addition, low levels of unemployment across the economy mean that the construction industry will have to compete harder against other industries to fulfil its labour requirements. There will be skills shortages if replacement falls below the yearly forecasted requirements. These will be most acute in the largest occupations such as carpenters & joiners, bricklayers, plumbers and electricians. The steady loss of workers due to ill health is something the industry can no longer afford to accept.

The UK's Health and Safety Commission (HSC) has launched a 'Revitalising' initiative which has set targets for industry to:
reduce the number of working days lost per 100,000 workers from work-related injury and ill health by 30% by 2010

- reduce the incidence rate of fatal and major injuries by 10% by 2010
- reduce the incidence rate of cases of work-related ill health by 20% by 2010
- achieve half of the improvement under each target by 2004

Without a considerably greater emphasis on occupational health by the construction industry than at present, these targets, or any more challenging targets that the industry might set for itself, stand little chance of achievement.

CLOSING REMARKS

The success of any country's construction industry depends on the commitment, innovation and productivity of its people at all levels, managerial, professional, skilled and unskilled. Construction needs workers who are healthy and motivated. APaCHe (A Partnership in Construction Health) is a new UK-based partnership between industrialists, academics and government with the aim of achieving a step change in the physical, psychological and social health of all those involved in the industry. The vision is a construction industry with:

- healthy workers
- healthy work systems and practices
- healthy work organisations

The dire situation of ill-health in construction is not going to change overnight, but at least some organisations seem to be moving in the right direction.

REFERENCES

[1] **Anon**, 1997a. Widow of asbestos victim wins substantial damages. Safety and Health Practitioner. May: 5.

[2] **Anon**, 1998a. Workstation and job design failures cost employer. Health & Safety Bulletin. January, 265: 3.

[3] **Anon**, 1998b. British Coal loses landmark compensation case. Health & Safety Bulletin. April, 268: 22-23 (The full High Court judgement from 23/1/98 can be downloaded at http://www.open.gov.uk/courts/court/qbdind.htm).

[4] **Anon**, 1998c. Record payment for hand vibration disease. Health & Safety at Work. 147, May: 6.

[5] **Beck**, M H. 1990. Letter to editor. British Medical Journal. 301: 932.

[6] **Berger**, J. 1998. Cement Dermatitis – an International Problem, Proceedings of CIB W99 Conference, Environment, Quality and Safety in Construction, Lisbon, June: 1-8.

[7] **Burkhart**, G. et al. 1993. Job Tasks, potential exposures and health risks of labourers employed in the construction industry. American Journal of Industrial Medicine. 24: 413-425.

[8] **Confederation of British Industry** (CBI) in Don, P. (1997), Workplace ill-health, Safety Management, British Safety Council, May, p.1, ISSN 0951 2624.

[9] **Croner** (1998) TUC urges asbestos switch. Construction safety Briefing, Croner Publications Ltd., Iss 35, August, p.3.

[10] **DTI**, 2000, Excellence and Opportunity, a Science and Innovation Policy for the 21st century, 2000, Department of Trade and Industry, para 33, p10.

[11] **DTI**, 2001, Opportunity for all in a World of Change – A White Paper on Enterprise, Skills and Innovation, 2001, Department of Trade and Industry, section 2.

[12] **E&P Forum** (1993) Health management guidelines for remote land-based geophysical operations (Report No. 6.30/190). Oxford: Words and Publications.

[13] **European Commission** (1995) Labour Inspection (Health & Safety) in the European Union Senior Labour Inspectors Committee. Copies available from: Unit 5 Accident/Injuries, The European Commission, The Plateau de Kirchberg, L-2920 Luxembourg

[14] **European Commission** (1997) Labour Inspection (Health & Safety) in the European Union – A Short Guide (Austria, Finland, Sweden). Senior Labour Inspectors

Committee. Copies available from: Unit 5 Accident/Injuries, The European Commission, The Plateau de Kirchberg, L-2920 Luxembourg

[15] **ECI**, (1995) Total Project Management of Construction Safety, Health and Environment, European Construction Institute, 2nd Edition, Thomas Telford, London: pp. 206, Editors: Gibb, A.G.F., Tubb, D. & Thompson, T. ISBN 0-7277-2082-1.

[16] **Fellows**, R, and Lui, A. (1997) Research methods for construction. Oxford: Blackwell Science.

[17] **Gibb**, A.G.F. Gyi, D.E. & Thompson, T. (eds) The ECI guide to managing health in construction, 1999, Thomas Telford, London, 170 pp. ISBN 0-7277-2762-1.

[18] **Gründemann**, R.W.M. & **van Vuuren**, C.V. (1998) Preventing absenteeism at the workplace: a European portfolio of case studies, European Foundation for the Improvement of Living & Working Conditions, Dublin, Ireland.

[19] **Gyi**, D.E., Haslam, R.A. & Gibb, A.G.F. (1998) Case studies of occupational health management in the engineering construction industry, Occupational Medicine, Vol. 48, No. 4, pp. 263-271, ISSN 0962 7480/98

[20] **HSE**, 1998. Ignore workers health and profits will suffer warns chairman at launch of new HSE health campaign. Health and Safety Executive Press Release. 22 May, E114: 98.

[21] **Hunting**, K L. 1994. Surveillance of Construction Worker Injuries through an Urban Emergency Department. Journal of Occupational Medicine. 36 (3): 356-364.

[22] **Madine**, V., 2000, The stress timebomb, Building, The Builder Group, London, 3 November, pp. 20-22.

[23] **Rosen**, R H & Freeman, S. 1992. Occupational contact dermatitis in New South Wales. Australian Journal of Dermatology. 1-10.

ECONOMIC ANALYSIS OF SAFETY RISKS IN CONSTRUCTION

Fernando Santos
Tabique lda, Braga, Portugal

J. E. Marçal,
Earth Tech lda, Lisboa, Portugal

Luis Bragança, Sonia Elias
Universidade do Minho, Braga, Portugal
tabique@elix.pt

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 *Douro Center*.

The *Douro Center* project is situated in the centre of the city Vila Real. The area is destined to become a luxury two-storey shopping centre, designed for leisure, restaurants and shopping and containing a three-storey underground car park. The construction area covers around 150,000 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.

INTRODUCTION:

The Safety and Health Coordination Staff of the Douro Center Project, Vila Real, 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 11 September 2000, and project completion by the 21 March 2002, approximately a year 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.

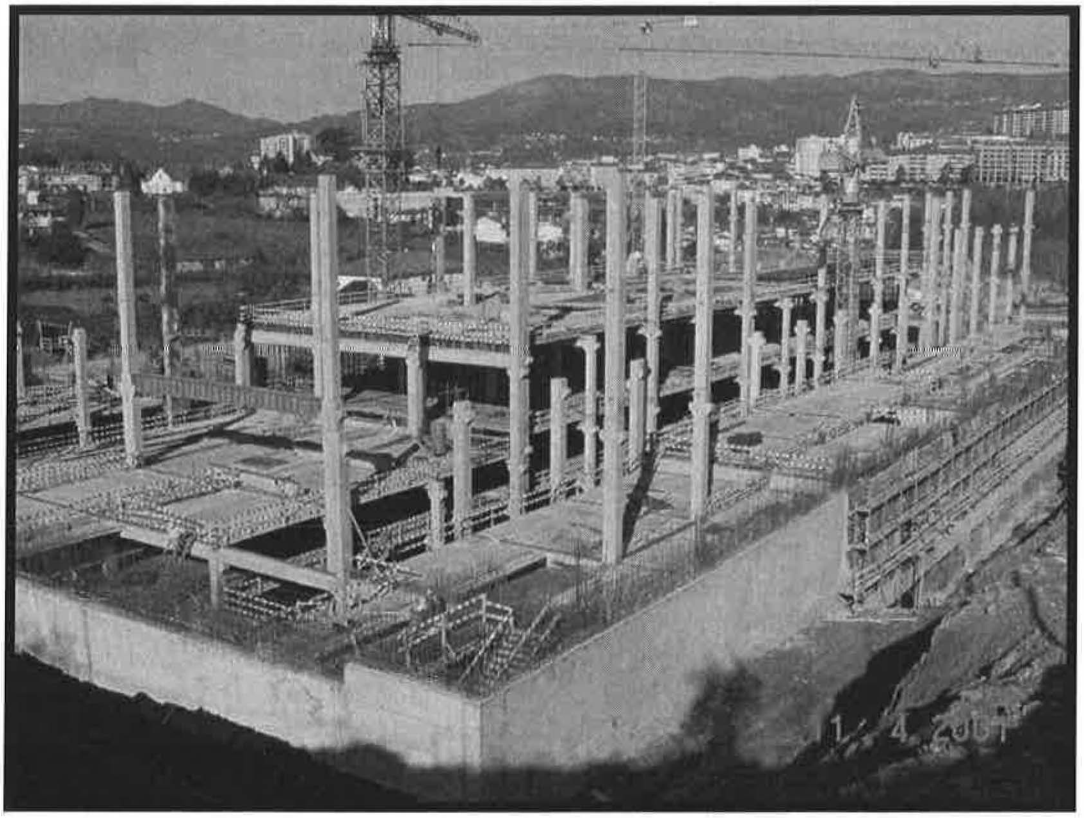


Figure 1. Panoramic view of Douro Center

EXPERIMENTAL:

Having a detailed working programme of Douro Center 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 1104 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.

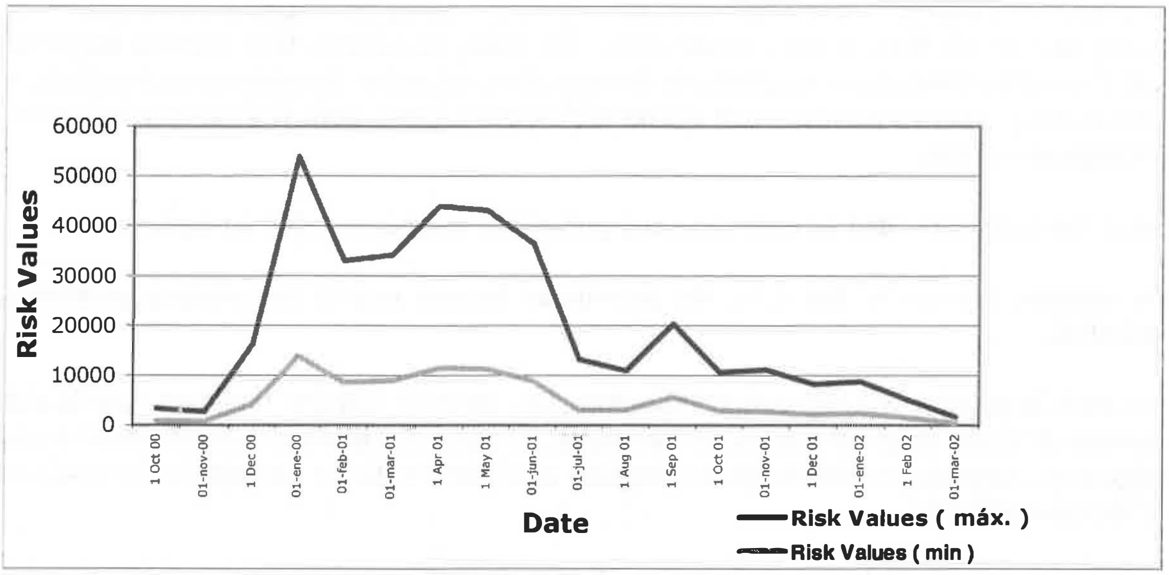
After that treatment, the simulation values of risk to both situations that will be simulated is added. One corresponds to total inexistence of prevention and the other to full prevention measures, and a study of both risk situations is done, having the histogram of the work plan related to working programme, as its basis.

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.

Table 1. Douro Center – Risk Values Monthly



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 Douro Center, with a project value of 35 millions of Euros, results in the following costs:

- Costs of implementation of prevention measures
  (2,00%) ~ 0.7 millions Euros

- Potential costs of non-safety
  (7.72) ~ 2.7 millions Euros

- Potential risk of added costs due to the non-existence of prevention
  (5.72%) ~ 2 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.

CONCLUSION:

This study applied to the Douro Center project, in Vila Real, 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".

REFERENCES

[1] Machado L. (1996), In Manual de Segurança no Estaleiro, (AECOPS, ed.), Portugal
[2] Alves Dias J. (1997) In Plano de Segurança e Saúde (IDICT, ed.), Portugal
[3] Reis C. (1998) In Análise Económica de Segurança na Construção, (Universidade do Porto, ed.), Portugal
[4] Santos J. M, Rodrigues M. F., Baptista M. A., Santos Reis S., Maduro Roxo M. (1999), In Coordenação de Segurança na Construção, perspectivas de desenvolvimento, (IDICT, ed.), Portugal
[5] Soeiro A., Almeida Santos F. M., Reis C. (1999), In Economic Overview of construction safety, (Singh A., Hinze J., Coble R.J., ed.), USA
[6] Alves Dias J. (1999), In Safety and Health on Construction Sites (CIB 99, ed.), England

WORKING IN SUNSHINE- THE COST OF SKIN CANCER IN THE CONSTRUCTION INDUSTRY

Catherine Pritchard
Department of Building and Environmental Health, The Nottingham Trent University (UK)
catherine.pritchard@ntu.ac.uk

Sun tanned skins are synonymous with the construction industry and currently many associate suntans with health. The fact that a suntan and sunburn is the first sign of skin damage has yet to be recognised by the public and outdoor workers. Over a period of time skin damage caused by ultra-violet light can result in skin cancer. This is one of the commonest forms of cancer and continues to increase despite the risk factors and controls being well recognised. The costs of these types of cancers have an impact on the individual, their family and the health services. In Britain it is estimated that skin cancer costs the health service £34 million annually.

The outdoor nature of the construction industry exposes workers to the effects of ultra-violet radiation and along with the use of various carcinogenic compounds results in a high rate of non-melanoma skin cancer. Workplace health promotion provides an opportunity to address this disease in a practical manner. Whilst the costs specifically related to skin cancer and the construction industry are yet to be quantified evidence indicates that there are cost benefits of such workplace initiatives.

The paper will discuss the impact of skin cancers on construction workers. Evidence from previous workplace health promotion initiatives will highlight the fact that behavioural change can take place via the use of effective and targeted health promotion initiatives in this area and the economic impact of these approaches.

Health care costs are an important burden on societies and they continue to rise on a year on year basis. It has been acknowledged that many diseases including skin cancer are preventable and workplace health promotion a mechanism to achieve this. As a major employer of outdoor workers, the construction industry possesses the potential to improve the health of its workers by reducing exposure to the risk of skin cancer. The challenge to health promoters is how best to ensure that this knowledge is translated into best practice in the construction industry and the potential cost effectiveness of this approach.

THE HEALTH IMPACT OF SKIN CANCER'S ON CONSTRUCTION WORKERS

Cancers are the uncontrolled proliferation of cells and in particular circumstances metastases arise that spread the cancer to other parts of the body. Exposure to sunlight is known to be beneficial to health however excessive exposure can result in harmful health effects. Ultra-violet radiation (UVR) is a form of non-ionising radiation that forms part of the electromagnetic spectrum. It is made up of three components covering the wave band for each section. UV-C 100-280nm, UV-B 280-315nm and UV-A 315-400nm (Tenkate,1999). Under specific circumstances, and dependant on individuals' risk factors, exposure to UVR may result in the skin becoming reddened and result in sunburn or erythema in the short term. Severe cases of erythema may result in inflammation, blistering and peeling of the skin. Long-term damage is caused by such exposure with cumulative exposure resulting in premature ageing of the skin but of more significance is the potential for the formation of skin cancers. Exposure to sunlight is the most important risk factor for the development of skin cancer (Cancer Research Campaign, 1995).

There are four clinical types of malignant melanoma the most dangerous form of skin cancer:

- Lentigo maligna – presents itself as a brown stain on the skin with the development of a central black nodule.
- Acral lentiginous melanoma – presents itself as extensive irregular pigmentation with a dense black central area.
- Superficial spreading melanoma – presents itself as an irregular shaped pigmentation with the central area being inflamed.
- Nodular melanoma – presents itself as a dense pigmented lesion with an irregular outline.

It is believed that individuals at greatest risk are those not necessarily exposed to sunlight on a daily basis, therefore seasonal outdoor workers (Campbell & Birdsell, 1994) as well as office workers may be at increased risk (Elwood et al, 1985). Elwood and Jepson (1997) demonstrated a significant positive association for malignant melanoma with an odds ratio of 1.71 for intermittent exposure as mentioned in the groups above and a significant reduction in the odds ratio 0.86 for those with heavy occupational exposure, therefore indicating that long-term chronic occupational exposure at a relatively constant dose may provide a degree of protection from malignant melanoma. The group most at risk are therefore those whose skin type do not tan easily and are exposed on an intermittent basis such as construction managers and electricians. Individual risk factors are affected by their skin type:

Table I. Classification of skin types

Skin type	Minimum erythemal UV dose Jm –2	Classification
1	150-300	Never tans, always burns
2	250-350	Tans with difficulty, burns frequently
3	300-500	Tans easily, burns rarely
4	450-600	Always tans, never burns
5	600-1000	Rarely burns tans profusely Genetically brown skin
6	1000-2000	Never burns deeply pigmented Genetically black skin

Associated with skin type are those individuals with a large number of naevi, which is believed to be the single greatest predictor of melanoma risk (Mclean & Gallagher, 1998) as are those with blue, grey or green eyes and red or fair hair (Elwood, 1990). Skin areas such as the torso that are intermittently exposed have seen the greatest increase in melanomas (Bulliard & Cox,2000).

The majority of construction workers are at increased risk from the development of Non-melanoma skin cancers that make up 90% of all skin cancers and are made up of two clinical types:

- Basal cell carcinomas – are also known as rodent ulcers. The tumours present as a lump or scaly patch that often has raised edges. These types of cancers are linked to exposure at an early age (Mclean & Gallagher, 1998)
- Squamous cell carcinomas – present as a thickened red spot, which may bleed or crust without healing. These types of cancers are linked to cumulative lifetime exposure (Mclean & Gallagher, 1998).

Of the two forms of non-melanoma skin cancers Basal cell carcinoma is the most common and is unusual as it does not spread, however if untreated it can cause disfigurement. Squamous cell carcinomas account for 20% of the cancers (Ross, 1988) but are able to metastases and therefore have a higher mortality rate (Skinner, 1997).

In addition to direct exposure to the sun, construction industry workers may also be exposed to a synergistic effect from the use of materials on site such as polycyclic hydrocarbons found in a range of oil and oil products including cutting oils, asphalt and tars (Ross,1988). It is believed that these products may not only act as carcinogens themselves, but also increase photo-sensitisation (Webb, 1992). The construction industry therefore needs to consider more fully the health of its workforce, by carrying out comprehensive risk assessments that focus on the individuals' risk factors as well as the work undertaken.

THE PREVENTION OF SKIN CANCER

Exposure of the skin to sunlight is the most important risk factor for the development of skin cancer, and whilst it is recognised that outdoor work is inextricably linked to the construction industry, effective job planning can help. The avoidance of operations during the mid-day sun may be the only control method available in certain countries together with the adoption of flexible working hours. Greater use of shaded areas could result in the minimisation of risks by planning a suitable system of work.

In addition to this, skin cancer risks can be reduced by the use of personal protective clothing. This can provide a high degree of protection for outdoor workers, but the effectiveness of any clothing is dependent upon:

- Weave – tight weave will transmit less UVR
- Colour – dark colours transmit less UVR
- Surface reflectivity – light coloured surfaces reflect
- Weight – thicker fabric transmits less UVR
- Stretch – stretch increases transmission
- Water – protection decreased when cloth is wet

Clothing may therefore provide the only defence in the initial stages of a construction project where most of the work is executed in the open. The use of tightly woven and light coloured clothes covering the torso and arms and the use of hats that cover the neck are key methods of protection.

Sunscreens are an alternative method of skin protection. By application to the skin, sunscreen blocks the majority of UVB however increasingly broad-spectrum sunscreens are being introduced that also block UVA (Mcgregor & Young, 1996). All sunscreens are allocated a Sun Protective Factor (SPF) rating according to the amount of UVR that is filtered out. There are, however a number of problems with the use of sunscreen as opposed to the other protection previously mentioned. Application of sunscreen should take place prior to exposure to the sun and be applied liberally to the exposed skin and reapplied on a regular basis. In practice this advice may not be followed consistently. Indeed it has been demonstrated that products with an SPF of 15 will generally only be applied to give protection equivalent to SPF3-7 (Mclean & Gallagher, 1998) and certain areas of the body may be missed on application. In addition to this the product advice to apply liberally and frequently may not be adhered to due to the cost implications' as those products with a higher SPF are invariably more expensive. Other problems that have been reported are that individuals may suffer an adverse reaction to compounds contained within the products that may affect consistent use and photo-degradation can reduce the efficiency of the sunscreen. On an external worksite the application of sunscreen may be cumbersome due to the greasy nature of the product and with inadequate welfare facilities this may be an inappropriate method of prevention.

The effectiveness of sunscreens in relation to positive health benefits appears to be inconclusive which is of concern, as the use of sunscreen is increasingly becoming one of the primary methods used by the public in order to protect themselves. Research indicates whilst sunscreens afford protection against sunburn and actinic keratoses, that is a precursor to squamous cell carcinoma, there appears to be little evidence to demonstrate its effectiveness in protecting against basal cell carcinoma (Mclean & Gallagher, 1998) and it has been noted from epidemiological studies that there appears to be an increased risk of melanoma, although animal experiments do-not support this (Autier et al, 1995)(Thompson et al, 1993). It is important to note that demonstration of a positive association between use of sunscreen and skin cancers is difficult to prove as there may be a number of confounding factors including the fact that susceptible individuals may delay or avoid sunburn resulting in prolonged exposure to UVR and as sunscreens cannot remove all UVA and UVB then this may increase the risk. It can therefore be seen that for out door workers there may be some benefits in the use of sunscreens, however they should only be used as the final line of defence when the other options above have been adopted.

Linked to all sun protection practices on site are our knowledge, attitudes and behaviour. Tanned skin in the 1800's was associated with peasantry and outdoor workers. In recent times with the advent of a greater degree of travel a suntan has become a sign of affluence and associated with well-being. Gender differences are apparent in both the area of knowledge and behaviour. Fewer men than women believed that sun exposure would affect their risk of skin cancer (Cambell & Birdsell, 1994). This is worrying as Streetly & Markowe (1995) found that there was a 190% increase in registration rates for men over the period of 1971-1989 and a corresponding rise of 137% for women. This is an important public health issue as male mortality rates are higher due to presenting later with the disease and therefore cure rates lower. Late presentation may also be due to the fact that backs are the most common location and therefore they may not be aware of the lesion. In addition to this as has been seen they are less knowledgeable about the disease and are less likely to respond to traditional health education approaches (Streetly & Markowe, 1995).

Outdoor workers are an interesting group as they are estimated to be exposed to between three to eight times the solar UVR exposure than indoor workers (Tenkate, 1999) (Stepanski & Mayer, 1998). Work carried out by Stepanski and Mayer (1998) that further developed work by Girgis yielded interesting results in relation to skin cancer risks. They carried out an observational study of a range of workers including construction workers. It was found that only 40.4% of workers had adequate protection somewhat worrying when it is considered that outdoor workers receive 6-8 times the dose of UVR than indoor workers spending 7.94 hours per day outside.

WORKPLACE HEALTH PROMOTION

Workplace health promotion is a relatively new concept in Britain. The focus on the workplace may well prove to be an important area to provide health messages, as there is the potential for a number of adults to fall through the net of health promotion messages. Hill (1992) found that, in Britain, women and children are the principal recipients of health promotion messages, therefore in light of this Glasgow et al (1993) suggest that one of the major rationales for conducting such activities is to influence those who are unlikely to engage in preventive health behaviour. Naidoo and Wills (1994) indicate that of all groups adult males come into contact with health care services to a lesser extent than any of the other population groups, but make up 3/4 of the workforce, so health messages in the workplace can be of vital importance to the health of this particular group. It is however recognised that blue male collar workers and those salaried on an hourly basis are less likely to become involved in health promotion initiatives (Gebhant & Crump, 1990) (Stonecipher & Hyner, 1993). This all links to the problems that can be experienced on construction sites.

Evidence related to the benefits of a health promotion approach has predominantly come from America, Scandinavia and Japan (Dugdill & Springett, 1994). Much of the work from these countries have focused on the economic benefits as spiralling employer contributions to health care costs have resulted in new initiatives to try and reduce insurance premiums. Research has found numerous economic benefits (Biener et al, 1993; Bertera, 1990) and improved relations with staff. Companies actively involved in health promotion have noted an improvement in the health of their workforce that has manifested itself as a decline in the level of absence (Knight et al, 1994; Jeffrey et al, 1993), increased productivity and improved staff morale (Dugdill & Springett, 1994). It must be considered that the roles of economic evaluations are limited in demonstrating a causal link between health promotion and change in the health of the employee population (Midha & Sullivan, 1999). Concerns have also been expressed over the ethics and appropriate application of workplace health promotion arguing that it can be utilised as a management control strategy and detract from employee health (Midha & Sullivan, 1999). One of the main concerns is in relation to the point of intervention, as this should take place at the three levels of information provision, policy development and in order to underpin these two the organisational perspective. This is of particular importance when considering skin cancer as no one method will result in the reduction of incidence.

COST OF SKIN CANCER AND ITS PREVENTION

Estimates vary for the rate of increase of skin cancer with an estimated doubling of incidence of malignant melanoma every 10 years, with most populations showing an average rate of increase of between 3-6% per annum (Skinner, 1997). In Britain, there has been a dramatic rise in cases of skin cancers with the British lifetime risk of contracting malignant melanoma being 1 in 200. It is estimated that the incidence of all skin cancers is approximately 40000 per year.

The rise in the number of cases presents a cost to the individual, the employer and to the health service. The care alone of patients with skin cancer was estimated in 1996 to cost £34 million annually and yet 80% of all skin cancer deaths are preventable (Stott, 1999). The economic effectiveness of skin cancer health promotion initiatives have been assessed in a number of countries and interesting results have highlighted that if a general population can benefit from health promotion in this arena then targeted workplace initiatives for construction workers could reduce the burden of this disease.

Mackie (1992) utilised information leaflets and referrals from General Practitioners to specific melanoma clinics with a resultant increase of 278% referrals and a fall in mortality was observed in women three years later. A study in Trentino Italy demonstrated the effectiveness of the use of sun safety media campaigns when over a period of 1977-1985 22.3 lives were saved due to early diagnosis with a cost saving to the health service of almost half a million dollars (Cristofolini, 1993). Australia has the highest incidence of skin cancer in the world and one of the most effective sun safety health promotion campaigns. Using a do nothing comparator a 20 year campaign has been estimated would avoid 4300 premature deaths with a net saving to the government of $AUD 103 million (Carter et al, 1999).

DISCUSSION

Much of the research related to incidence and mortality of skin cancer have focused on out-door workers as a generic group in preference to considering specific trades or industries. This provides a valuable insight into the potential effect of this disease in the construction industry. Outdoor workers are more likely to suffer from the non-melanotic skin cancers (Marks, 1983) with a two-fold increase in incidence over those who work indoors (Gallagher, 1989). In addition, outdoor workers have higher rates of skin damage than the general population (Webb, 1992) and a study that focused on mortality in the construction industry in the USA found elevated mortality rates for brick-masons caused by melanomas (Robinson et al, 1995).

Male mortality from skin cancer is twice that of women (Marks, 1991). This may well be linked to the fact that only 35% of men believe that sun exposure increases their risk of contracting skin cancer (Campbell & Birdsell, 1994) and the resultant impact that this has on prevention practices. The construction industry predominantly employs men and as they are more likely to be outdoor workers (Campbell & Birdsell, 1994), they are at increased risk of non-melanotic skin cancers.

Assessing the impact of skin cancer on the construction industry is problematic due to the long latency period and non-occupational exposure to ultra violet light. On the death certificates all cases where an industrial disease is mentioned are passed to a coroner for further investigation, however skin cancer may not be identified as such, even though squamous cell carcinoma is a prescribed industrial disease, and therefore overlooked. In addition to this there is no statutory obligation to record the occupation and between 1971-1990 it is estimated that only 41% of death certificates contained this information (ONS, 1997), thus limiting the reliability of the information. This is compounded in the construction industry as many people leave the industry due to ill health that has been induced or aggravated by their work and are therefore lost from the system. Within the industry there is a lack of centralised medical records as many people on site are sub-contractors. Many site workers may change jobs frequently, or are moved on by their companies and certainly if they have suffered from other long-term chronic injury such as manual handling injuries there last job may well not be related to the industry. The temporary nature of the worksites therefore provides a special difficulty in tracing this group.

Health promotion, prevention and education each have an important role in the long-term control of skin cancer in the construction industry. Approaches advocated to prevent the occurrence of the disease include the avoidance of the midday sun 11-3, adequate protective clothing and the use of an appropriate sunscreen with an SPF of 15 or more, however all of these measures need to be underpinned by good health education and organisational change in order to change behaviour. Health education interventions carried out in Australia on outdoor workers (telecommunication and electricity supply workers) utilised a range of education health intervention methods in order to encourage out-door workers to cover up. This included informative posters, videos, individual resource material including protective equipment and dermatological screening of the outdoor workers. Support was obtained from both staff and management in order to ensure the maximum rates of participation in these studies. In all of the interventions there was a significant improvement in the outdoor workers' knowledge about skin cancer and their behaviour in the sun in comparison to a control group, thus demonstrating the benefit of an educative approach. The work by Girgis et al (1994) demonstrated that as a result of the intervention there was a 16% increase in the outdoor workers using a high level of solar protection.

CONCLUSION

Construction workers predominantly work outside and therefore are at increased risk of certain forms of skin cancer. The spiralling incidence of this disease means that it is time to take action in order to improve their health by protection against skin cancer.

Appropriate and targeted workplace health promotion initiatives could be the first stage in the control of this form of cancer. The cost benefits related to populations have been demonstrated and therefore its application to construction sites could provide an appropriate strategy for the prevention of skin cancer.

ACKNOWLEDGEMENTS

Many thanks to Mr Geoff Carter and Dr Heather Roberts. Support for this work has been provided by The Nottingham Trent University.

REFERENCES

[1] Autier. P. et al. (1995). Melanoma and use of sunscreens: an EORTC case control study in Germany, Belgium and France. *International Journal of Cancer*.61, 749-55.

[2] Bertera R.L.(1990) Planning and Implementing Health Promotion in the Workplace : A case study of Du Pont Company experience. *Health Education Quarterly*. 17, 3, 307 – 32.

[3] Biener L et al. (1993) Recruitment of Worksites to a health promotion research trial. *Journal of Occupational Medicine*. 36, 6, 631 - 636.

[4] Borland, R.M. et al. 1991. The impact of skin cancer control education package for outdoor workers. *The Medical Journal of Australia*. 154 May 20.

[5] Bulliard.J.L.,& Cox.B. (2000). Cutaneous malignant melanoma in New Zealand: trends by anatomical site, 1969-1993. *International Journal of Epidemiology*.29, 416-423.

[6] Campbell, H.S. & Birdsell J.M. 1994. Knowledge, beliefs, and sun protection behaviours of Alberta adults. *Preventative Medicine*. 23, 160-166.

[7] Cancer Research Campaign. 1995. *Fact sheet*.

[8] Carter. R., Marks. R., & Hill, D. (1999). Could a national skin cancer primary prevention campaign in Australia be worthwhile?: an economic perspective. *Health Promotion International*. 14,1, 73-82.

[9] Cristofolini. M. et al.(1993) Analysis of the cost effectiveness ratio of the health campaign for the early diagnosis of cutaneous melanoma in Trentino, Itlay. *Cancer*.71,2, 370-4.

[10] Dugdill J & Springett J . (1994) Evaluation of workplace health promotion: a review . *Health Education Journal* 53,337 - 347.

[11] Elwood, J.M. 1990. Malignant melanoma in England: risks associated with Naevi, freckles, social class, hair colour and sunburn. *International Journal of Epidemiology*. 19, 4, 801-810.

[12] Elwood. J.M., et al (1985). Cutaneous melanoma in relation to intermittent and constant sun exposure-The Western Canada melanoma study. *International Journal of Cancer*. 35, 427-433.

[13] Elwood. J.M., & Jopson. J. (1997). Melanoma and sun exposure an overview of published studies. *International Journal of Cancer*. 73, 198-203.

[14] Gallagher, R.P. et al. (1989). Is chronic sunlight exposure important in accounting for increases in melanoma incidence? *International Journal of Cancer*. 44,813-15.

[15] Gebhant DL & Crump CE (1990) Employee fitness and wellness programmes in the workplace. *American Psychology* 45,262 - 272.

[16] Girgis, A. et al. 1994. A workplace intervention for increasing outdoor workers' use of solar protection. *American Journal of Public Health*. 84 ,1, 77-81.

[17] Glasgow R.E. et al (1993) Participation in worksite health promotion : A critique of the literature and recommendations for future practice. *Health Education Quarterly* 20,3, 391 - 408.

[18] Godkin, G.A. (1991). Changing workplace behaviour: Skin cancer protection. *Journal of Occupational Health and Safety-Aust NZ*. 6, 477-482.

[19] Hill I M (1992) Health promotion in the British workplace: a suitable case for treatment ? Occupational Medicine 42,175 - 178.

[20] Jeffrey R.W. et al (1993) Effects of Worksite health promotion and illness related absenteeism . Journal of Occupational Medicine 35 ,11, 1142 -1146.

[21] Knight K.K. et al. (1994) An evaluation of Dukes University's Live For Life Health Promotion programme on changes in workers absenteeism. Journal of Occupational Medicine 36,5, 533 - 536.

[22] Mackie. R.M.(1992). Audit of public education campaign to encourage earlier detection of malignant melanoma. *British Medical Journal.* 304, 1112-1115.

[23] Marks, R et al. (1983). Non-melanotic skin cancer and solar keratoses in Victoria. *Medical Journal of Australia.* 2,433-34.

[24] Marks, R. 1991. Public health evaluation of skin cancer campaigns. *Journal of Occupational Health and Safety-Aust NZ.* 7,5, 425-430.

[25] McLean. D.I.,& Gallagher. R. (1998). Sunscreens use and misuse. *Dermatologic therapy.* 16,2, 219-226.

[26] Mcgregor. J.M,.& Young. A.R.(1996). Sunscreens, suntans and skin cancer. *British Medical Journal.* 312,1621-1622.

[27] Midha, A. & Sullivan, M. 1999. Conflicting rationales for promoting health in the workplace. *Critical Public Health,* 9,3, 223-232.

[28] Naidoo J & Wills J. (1994) *Health Promotion: Foundation for Practice.* Balliere Tindall, London, Britain.

[29] ONS. (1997). Occupational cancer: the routine of cancer registration. S.O.London. Britain.

[30] Robinson, C. et al. 1995. Assessment of mortality in the construction industry in the US 1984-1986. *American Journal of Industrial Medicine.* July 28, 49-70.

[31] Ross, D. 1988. A look at skin cancer. *Occupational Health.* January, 420-422.

[32] Skinner, E. 1997. *Skin cancer. A brief review of incidence and causes.* Health Education Authority, London Britain.

[33] Stepanski. B.M,& Mayer.J.A. (1998). Solar protection behaviors among outdoor workers. *Journal of Occupational and Environmental Medicine.* 40,1, 43-48.

[34] Stonecipher L & Hyer G (1993) Health Practices before and after Work-site Health Screening. *Journal of Occupational Medicine* 35, 3, 297 – 306

[35] Stott.M.A. (1999). Tanning and sunburn: knowledge, attitude and behaviour of people in Great Britain. *Journal of Public Health Medicine.* 21,4,377-384.

[36] Streetly.A. & Markowe.H. (1995). Changing trends in the epidemiology of malignant melanoma: Gender differences and their implications for public health. *International Journal of Epidemiology.* 24,5, 897-907.

[37] Tenakate.T.D. (1999). Occupational exposure to ultraviolet radiation: a health risk assessment. *Reviews on Environmental Health.* 14,4,187-209.

[38] Thompson. S.C., et al. (1993). Reduction of solar keratoses by regular sunscreen use. *The New England Journal of Medicine.* 329, 16, 1147-1151.

[39] Webb, G. 1992. Solar radiation protection for outdoor workers. *Journal of Occupational Health and Safety-Aust NZ.* 8,6, 470-485.

COSTS FOR QUALITY, SAFETY AND HEALTH IN BUILDING SITES FOR RESTORATION OR MAINTENANCE WORKS

Renato Laganà
D.A.S.T.E.C. – Mediterranean University of Reggio Calabria (Italy)
renlagan@tin.it

The huge growth of interventions aiming at the restoration and the new use of ancient and recent structures has determined a closer attention to European firms. This specific field asks for the adoption of protective measures against all workers' forecast risks.

The recent Italian law about public works (109/94, art.32, c.2 and following integration's) provides for Safety and Co-ordination Plan, charging an obviousness in designing phases.

In July 2000, Italian Public Works Ministry issued some "Guidelines for costs and labour calculation". In the light of the latest directions we have to cope with, we have many important experiences in restoration or maintenance construction processes.

We evaluate any application condition for safety and health charges looking at quality performances.

Keywords: cost, quality, safety, building sites.

INTRODUCTION

In planning and creating a building generally take part many professionals who often play limited or autonomous roles if compared with the whole building activity.
The achievement of quality targets and the enforcement of rules for the safeguard of workers' safety and health, dictated by the latest EU regulations, are still far from the culture of many firms and designers.

New laws (laws by decree n.494/1996 and n.528/1999) make compulsory the specific knowledge about safety items in most interventions on buildings; but, since in Italy it is lacking, we can witness tacks based on superficiality or improvisation. In the building sector there is still an attitude stemming from an habit bolstered on rules linked to the ancient culture of accident prevention: all this causes the poor knowledge of safety problems involving every worker in the building process.

The creation of specific professionals in safety control field, enforced by law by decree n. 494/1996 caused among designers a general attitude of non involvement in safety responsibility.
We see that technicians' weak training on safety and quality matters, and the deep lag in quality culture by small and medium firms which constitute connective fabric of Italian production system make this situation worse.
All this helps improving the general result of non quality inside the productive process, penalising the building sector where they have not already clearly understood the problem of safety costs' quantification.

We would like to stress here some problems marking one of the most leading sectors in Europe, i.e. the intervention on already existing buildings by means of restoration, renovation and maintenance.

THE OPERATORS AND THE PROBLEM OF SAFETY COSTS

We started speaking about safety costs in Italy with the enforcement of law by decree n. 494/1996 art. 12. They were considered as an element to specify when drawing Co-ordination and Safety Plans (CSP); they must be assessed according to measures to be adopted, procedures to follow and the equipment's which are necessary to guarantee workers' health and safety in building sites operations.

The assessment of this charge is safety co-ordinator' s main task in planning phase since the law does not quote the role the designer has to play in the quantification of the global cost of the work. Up to few months ago there was not any specific indication about costs: only the law on Public Works (Merloni ter - n.415/1998) made a condition that costs must be specified and stressed in drawing call for tenders with the specific clause that they must not be liable to bidding marks – down.

Law Merloni-ter contents', specified in the latest Regulations, are based on the idea of "plan centrelines", which in its economic formulations (metric calculations, price list) has to include all charges stemming from Co-ordination and Safety Plans which become mandatory, because they cannot be modified any more after that the contract has been given. The technical instruments the firms must draw such as Safety Operational Plans (SOP) can introduce even equipment's or technologies different from those which had been budgeted for, even if they are inside the economic amounts forecast in the contract. This has to happen even in the case we must prepare a Substitutive Safety Plan (SSP) due to changes in procedures which have intervened during works.

Even in the last Conference held in London we stated that designer's and co-ordinator's activity have to perform contemporaneously. These two professionals must integrate their knowledge and together identify the project items on which the implementation of specific safety charges makes all the difference to quality achievement, and here we mean not only the achievement of project quality but even that of work's accomplishment.

A silly mark - down policy forced many businessmen to reduce or even completely eliminate the already in price list assessed charges, concerning minimal equipment's (DPI, tools in keeping with regulation, etc.) or operators' training activities.

We have recently noted that , in spite of laws indications, the "poor impact" of safety costs, generally assessed about 1% or 4% of the total price of the work, does not influence the policy of forestalling by means of strong marks – down which, in the end, will waste the implementation of measures for workers' health and safety.
In order to clear our minds from eventual wrong ideas which could stem from insufficient rules, the Public Works supervisory authority has improved its task, ensuring the compliance with laws.

In resolution n.37, 26.07.2000, they showed calculation procedure for determining labour cost influence in each sector of the work, because it is necessary, when assessing building cost, to identify all charges linked to the implementation of measures for workers' health and safety.
The specific role the designer has to play was specified in that regulation, with reference to what is written in art. n.35,paragraph 1, letter 1) in the General Code on Contract (D.P.R. 554/1999). When the designer draws the working plan of a work, he has to assess "the chart of percentage influence of labour amount (I_{MO}) for all different groups (generic or skilled workers) by which the contract is accomplished". The summation notation of prices per unit (P) for the amounts (Q) allows us to obtain construction cost related to a building:

$$C = \Sigma^1_n P\,Q$$

The price P is assessed by adding Materials, Transports and Labour prices to a "percentage calculated on it" of safety charges in addition to General charges and Earnings of undertaking.

The redaction of Safety and Co-ordination Plan, safety co-ordinator's duty, must include the assessment of all those costs which are "necessary for the preparation of procedures and equipment's that can guarantee the compliance with accidents prevention and the safeguard of workers' health in building sites".

From the ratio between total safety charges (SNC) and building cost (C) we can get the amount of average influence of safety (IS): IS = SCS/C

The Authority was compelled to make this clarification in order to create a pattern for safety costs' assessment to be adopted up to the enforcement of Code for Safety Plan in building sites in compliance with EU norms and Italian norms. This Code, issued by law n.109/1994 , comma 31 and its subsequent integration's and variations, still needs governmental approval.

The enforcement of this resolution finds many difficulties particularly about " the ways to assess total safety charges" and about the inclusion, among safety costs, of earnings of undertaking and VAT.

In the latest Resolution n.2 in 10.01.2001, Public Works supervisory authority intervened to clarify even more all doubts the operators had cast on it.

We see then the particular role the designer has to play: he has to be an active player in identifying safety costs. When the charges are included in prices (according to what is dictated by Public Works ministerial order n.145/ 19.04.2000, comma 5.1,i), he must determine analytically the share of these costs; when we are in front of charges considered as special (the presence in the building site of a doctor and ambulance, monthly meeting of workers, and so on), the designer must determine analytically their share in metric calculations. By adding these two charges we can determine total safety charges value (SNC) from which we can assess average cost fraction value (IS).

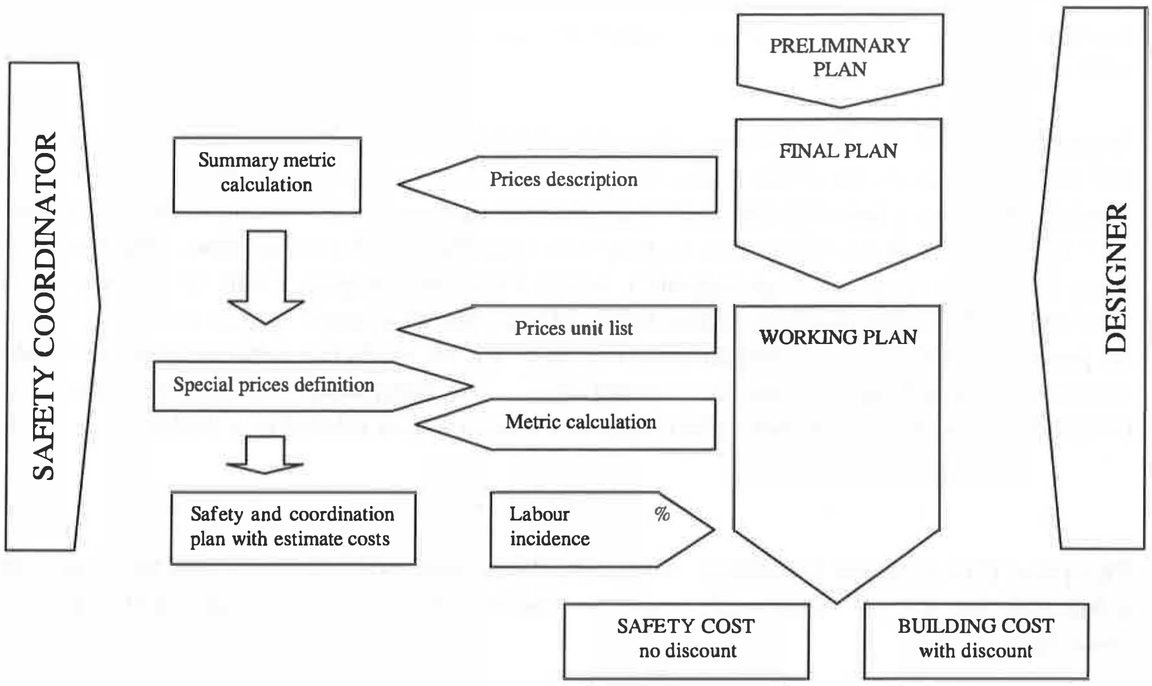


Figure 1. The building costs process definition.

As to the second "problem", they made clear that safety charges enunciated in call for bids must not be considered as including VAT or earnings of undertaking. In compliance with law, they are not subject to marks-down and "it would not make sense to subject to the same regulations even that amount of profits that can create a competitive element between operators".

TOWARDS THE DRAFTING OF AN OPERATIONAL PATTERN

The patent confusions there are people contract out a work, clearly reflect the way Italians work in watertight compartments. Many operators taking part in the building process do often work without keeping in mind that other professionals play an integrative role and without aiming at quality achievement.

The consequence of this , even because of ineffective controls on performing firms, is the lack of quality in building costs' assessment that leads to the loss of safety conditions that in their turn lead to a growing increase of site accidents.

This observation, I have already exposed in the paper I have presented in Lisbon conference, has stirred me to formulate a working hypothesis concerning planning activity on already existing buildings, based on the following aims:

- To achieve a better quality of planning activity and particularly in operational level;
- To improve, by means of an operational scale, the relationship between designer and co-ordinator so that the plan evolution occurs pari pass with safety choices;
- To implement all the knowledge we have of pre-existent building conditions (environmental, static, qualitative conditions);
- To identify, by prefiguring organisation hypothesis of the building site, all elements which will bring special safety charges;
- To achieve an high level of services performance quality.

AN OPERATIONAL PATTERN FOR INTERVENTIONS ON ALREADY EXISTING BUILDINGS

Pattern features have been drawn up to meet the following criteria:
Quality in drawing up building plan and particularly those working on already existing buildings;

- To create a method which considers safety costs from the first steps of planning;
- To improve the quality of working plan papers;
- To have a flexible method that can fit to all building interventions.

We can therefore point out the five steps in which the pattern is set out:

1st STEP – Delimiting the scope of the plan and team organisation

It is marked by many programmatic and organising meetings; it defines when and how to achieve plan quality. It finds expression in targets, in a chrono - program of planning time including meetings to check work progress.

2nd STEP – Widening planning themes

Implementation of all activities needed to start planning phase through a faithful survey of what already exists (geometrical, structural survey, research on materials), a microscopic analysis of environmental background conditions and of whatever is necessary to achieve an initial graphic definition of the plan. In this phase it is important to get all elements occurring to define creative aspects, putting even hypothesis on how the building site will work in order to forecast all costs.

In this phase safety co-ordinator begins to play an important role by doing a research on prevention aspects.

3rd STEP – Defining plan papers

After we have checked building site feasibility, we go on plan graphic drafting in its different aspects concerning architectural , structural and plant – engineering definition. We foresee co-ordination meetings among different professionals and technicians in order to check quality levels they have achieved, to tune technical requirements and to allow to draw operational, descriptive and performance specification.

Safety co-ordinator plays an active role and co-operates with the designer in order to define unit prices for each manufacturing and in order to identify better safety costs. He has to specify the features of building site area, its organisation, the possible presence of external factors which can bring some risks for the building site itself, risks linked to caring out some particular and risks that could be caused in surrounding areas, having as target the reduction to minimum levels or the avoidance of risks. By drawing PSC up he can qualify preventive and protective implementations for all manufacturing process establishing DPI enforcement; "special" implementations to achieve safety; safety interventions to be implemented in case of manufacturing lag and co-ordination between many firms and operators.

4th STEP – Working plan pre-verification

It is carried out through an accurate verification of planning elaboration's in compliance with what Quality Plan states. It takes place before the meeting between the professional in charge of the plan and the designers as it is foreseen by art. 37 of Italian law on Public Works which aims to:

- Verify the correspondence of plan drafting's with the mandate;
- Check the integrity of technical papers;
- Verify planning choices with hints emerging from geological and geotechnical surveys;
- Verify the integrity and accuracy of planning drafting's;
- Verify the suitability of adopted criteria for equipment's and structural calculations;
- Verify the correspondence of graphic drafting's and specifications containing appreciative metric calculation;
- Verify specification and contract papers;
- Verify building site feasibility through the control of papers concerning approvals and licenses required for the plan.

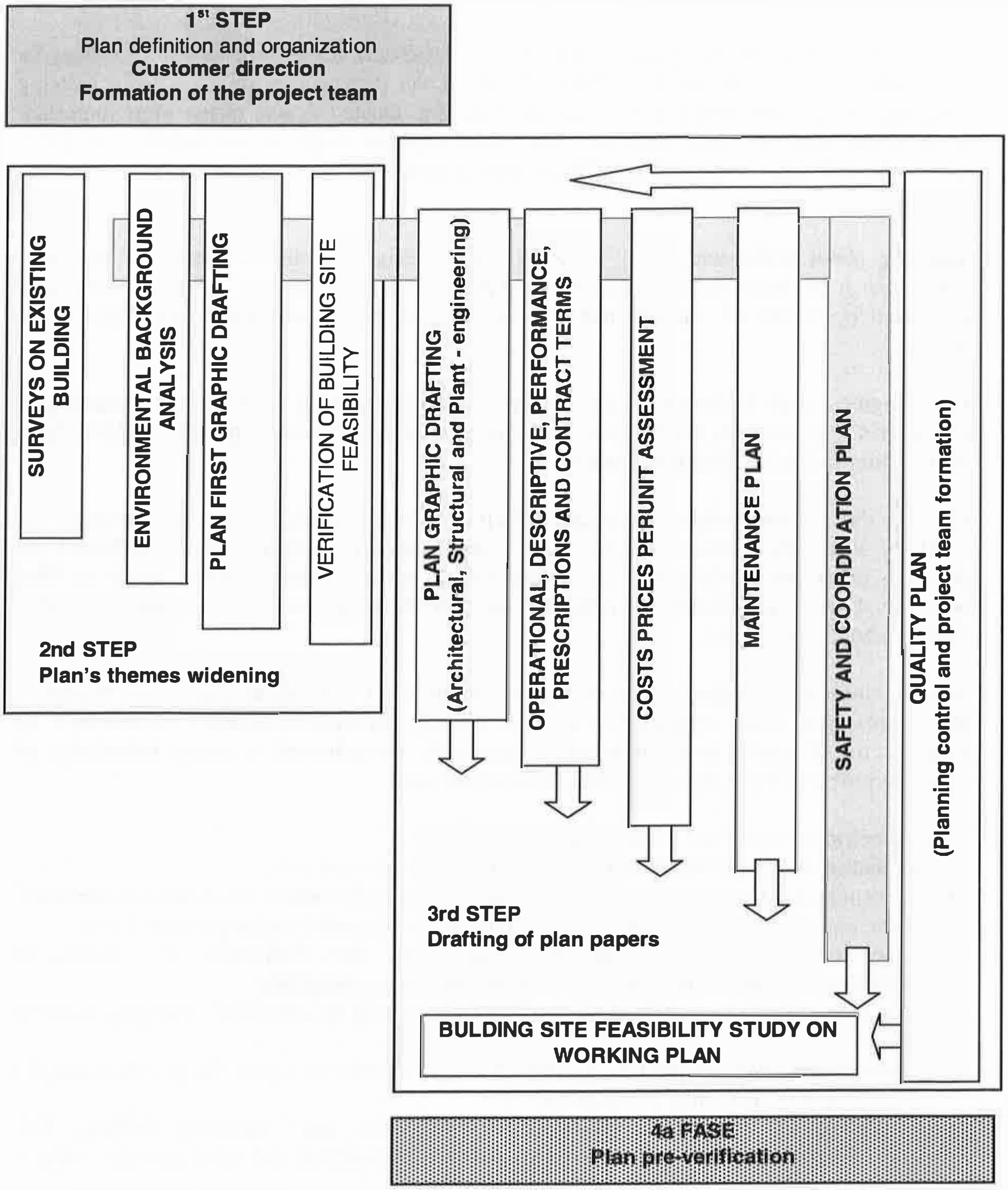


Figure 2. The proposed pattern.

APPLICATION OF THIS PATTERN ON AN INTERVENTION ON ALREADY EXISTING BUILDING. A CASE STUDY

During the drafting of the operational pattern we have seized the opportunity for testing its enforceability in a complex work which involved the intervention on an already existing building. We are speaking about a religious building, located in one of the most important roads in Messina, in Sicily, built of a reinforced concrete structure and bulkhead in 1952, which showed many structural instabilities due to materials' poor quality and poor planning solutions.

Speaking about health and safety terms in that building site, the building was notorious (remember it has been built in a period when prevention and workers' safeguard were only expressed by means of businessmen concern) as the roofing collapsed and killed three workers.

The designers' team in charge of drawing up a plan for structural recovery had, according to customer's requirements, to prepare even the restoration of functional spaces in order to have the building fitting the functional needs.

First we did a survey aiming to assess underlying ground conditions and to determine the entity of instabilities and the physic- chemical features of materials. Then followed the planning phase, when designers and safety co-ordinators worked together, since the first operational steps, to identify all aspects related to the achievement of a planning quality linked to costs assessment.

After having started project group, formed by an architect working as leader, two engineers for structural and plant – engineering surveys, an engineer working as safety co-ordinator, an engineer for economic assessment and a geologist, we achieved a patchy knowledge of structure problems by carrying out the following surveys:

1) Geometric survey of the existing structure;
2) Geometric survey of foundation structures by check pits and tests;
3) Determination of mass concrete mechanical features (sclerometric tests and pull–out tests, abstraction of cylindrical samples of hardened mass concrete for compression tests);
4) Determination of irons mechanical features by the abstraction of samples of reinforcements bars which underwent tensile tests in a special lab;
5) Tests performed on partition walls by flat jack, aiming to determine masonry working tension,
6) Monitoring of areas which had developed cracks in order to assess the presence and the development of instability phenomena;
7) Geognostic surveys with in situ tests continuous core sampling drilling, STP penetrometric tests, samples abstraction) and in labs (analysis and tests) in order to know subsoil conditions;
8) Seeking in the surrounding subsoil destabilising conditions (town water system leakage);
9) Historical and documentary research.

According to data which came to light during the survey, we have drawn up the preliminary planning proposal in order to get the first approvals, we have then cast intervention costs.

Once the study phase had been carried out, we started with the second phase in order to define working plan, preceded by a check of building site feasibility since we were going to intervene inside a urban area marked by very small clear spaces.

The implementation of reinforcement operations has been specified by planning previsions in operational terms, stressing for special works safety costs. We have specified the phases and methods in order to achieve operational quality.

Safety and Co-ordination Plan drawing has been carried out pari pass with the plan evolution, creating the basis, inside planning quality supervision process, of technical requirements and of definition of unit prices and costs.

Operational pattern steps, which at the beginning were marked by a chrono-program, underwent during working and in relationship with supervision activities, small adjustments which came from new working procedures.

CONCLUSIONS

The development and the adjustment of the pattern we have just exposed needs, in order to improve, some other verifications. By now, we are trying to test it on less complex situations and with different planning specifications.

Thanks to other practical implementations, we are becoming aware of the fact that the necessary condition to achieve quality is based on the relationship stemming from the project group or the sole designer and the safety co-ordinator from the very beginning of planning: this is the time when occurs the definition of the whole cost of building.

This interaction leads to a clear determination of plan costs, overcoming unpredictability that marked the first operational step in the enforcement of health and safety norms in working places and particularly in building sites.

If, in the organising phase, we pay attention to safety and quality problems, by studying in planning phase their solutions and their costs, quality of planning process will be higher and we will avoid higher costs in working phase.

REFERENCES

[1] R.Ainerdi, 1999, I costi della sicurezza in cantiere e la stima dei relativi costi, "Ambiente e Sicurezza",n.23 Italy.

[2] De Martino, C.G. Catanoso, 1999, I costi della sicurezza d.lgs. n.494/1996 e Merloni Ter: la stima dei costi della sicurezza, "Ambiente e Sicurezza", n.23. Italy.

[3] A.Trupiano,1999,I costi della sicurezza: oneri della sicurezza nei bandi di gara, "Ambiente e Sicurezza", n.23, Italy.

[4] V. Mainardi, 1999, I costi, il subappalto e le responsabilità, "Edilizia e Territorio –Il Sole 24 Ore", dossier "La nuova sicurezza nei cantieri", n.2, Italy.

[5] Autorità dei Lavori Pubblici, 2000, Determinazione del 26 luglio 2000, n. 37, Gazzetta Ufficiale della Repubblica Italiana, n. 221, Italy.

[6] D. Romeo, 2000, Le direttive dell'Autorità per il calcolo degli oneri, "Ambiente e Sicurezza", n. 18, Italy.

[7] Autorità dei Lavori Pubblici, 2001, Determinazione del 10 gennaio 2001, n.2, Gazzetta Ufficiale della Repubblica Italiana, n.26, Italy.

[8] C.G. Catanoso, 2001, Prime indicazioni sui costi della sicurezza, "Ambiente e Sicurezza", n.4, Italy.

[9] M.C. Casanova, M.E. Larranaga, 2000, Guidelines to implement Quality Systems on Building Sites for Industry, "Proceedings of the International Conference – Implementation of Construction Quality and Related Systems", 345 – 357. Lisbon. Portugal.

[10] V. Silva, R. Azevedo, 2000, Implementing quality systems in the rehabilitation of concrete structures. A case study, "Proceedings of the International Conference – Implementation of Construction Quality and Related Systems", 321 – 331. Lisbon. Portugal.

[11] M.C. Casanova, X.R. Ramon & P.A. Ribot, 2000, Quality Assessment On Project Engineering: A Global View, "Proceedings of the International Conference – Implementation of Construction Quality and Related Systems", 359 – 369. Lisbon. Portugal.

[12] R.G. Laganà, 2000, Safety in Building Maintenance Design, "Designing for Safety and Health Conference – Proceedings", London, U.K.

[13] R.G. Laganà, 2000, Quality and Safety Systems in Building Maintenance, "Proceedings of the International Conference () – Implementation of Construction Quality and Related Systems", 133 – 140. Lisbon. Portugal.

[14] R.G. Laganà, 2001, Recent technological systems and safety in cultural heritage building restoration, "Creative Systems in Structural and Construction Engineering" (Proceedings), A.A. Balkema, Rotterdam/Brookfield, Netherlands.

COSTS AND BENEFITS RELATED TO QUALITY AND SAFETY AND HEALTH IN CONSTRUCTION

Christian Weber
Suva, Lucerne (SWITZERLAND)
christian.weber@suva.ch

Despite the fact that accident frequency in the construction industry has been decreasing for decades, costs and thus premiums continue to increase inexorably. Since the bonus-malus premium system was introduced in Switzerland in 1995, companies have been highly motivated to enjoy the benefits of the bonus. In today's difficult economic climate, companies have realized that health protection is a factor for success that should not be underestimated. While companies with an excellent record pay an annual premium of around CHF 1,300 per employee, companies with high accident frequency are charged an annual premium of around CHF 6,800 per employee. This represents a difference of about 8 per cent in terms of wages. With this incentive, companies are also willing to invest in occupational safety.

It is actually difficult to make a precise statement about the cost savings that can be made for every franc invested. The easiest method is to make a statement based on a specific example. In 1990, Suva (the Swiss National Accident Insurance Fund) introduced a new safety guard for construction site circular saws. In the 10-year period since this safety guard was first put on the market, almost every saw in usc has been converted. It can be shown that the money invested has paid for itself many times over. While the investment cost of converting all the machines has amounted to around CHF 3.5 million, the annual savings in direct costs have amounted to about CHF 5 million.
By working closely with companies that have addressed occupational safety and health protection systematically for years, it is also possible to make a fairly reliable statement on costs and benefits over a wider scale. It becomes apparent that safety in the workplace must not be addressed in isolation but together with leisure-time safety and sickness. The synergies are obvious.

SUVA:

The Swiss National Accident Insurance Fund (Suva), a non-profit public organization, has been Switzerland's most important insurer for compulsory accident insurance since 1918. The benefits offered by Suva include insurance, rehabilitation as well as health protection in the workplace and during leisure time. With around 300 qualified safety specialists, Suva is in a position to investigate specific client situations and to propose individually tailored business branch and company solutions. With its comprehensive range of advisory and monitoring services, it supports companies in matters concerning occupational safety and health protection.

INTRODUCTION:

As in most other branches of business, the risk of accidents in the construction sector has been on the decline for decades in Switzerland while costs, and thus premiums, continue to increase inexorably. Since the bonus-malus premium system was introduced in Switzerland in 1995, companies have been highly motivated to enjoy the benefits of the bonus. In today's increasingly difficult economic climate, companies have realized that health protection is a factor for success that should not be underestimated. While companies with an excellent safety record pay an annual premium of around CHF 1,300 per employee, companies with high accident frequency are charged an annual premium of up to CHF 6,800 per employee. This represents a difference of about 8 per cent in terms of wages (Figure 1). With this incentive, companies are also willing to invest in occupational safety.

It is actually difficult to make generally valid statements about the cost savings that can be made for every franc invested. The easiest method is to make statements based on specific examples.

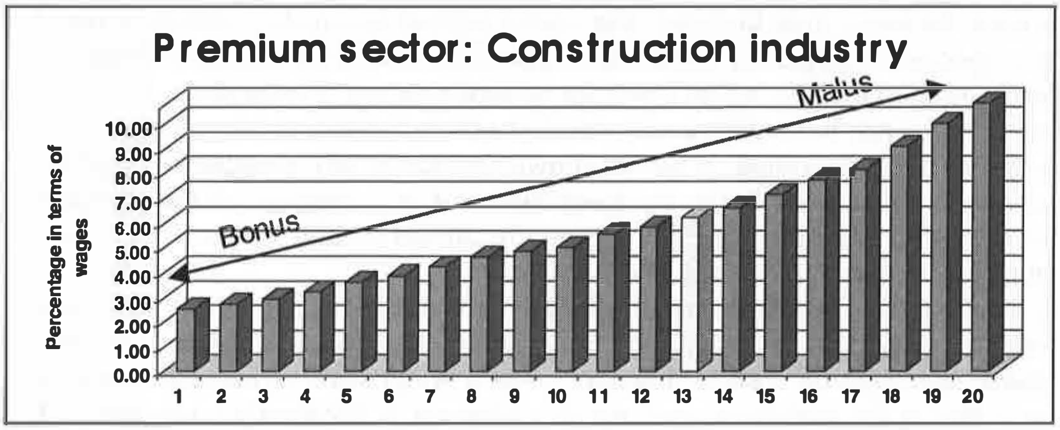


Figure 1. Bonus-malus premium system

A TYPICAL TECHNICAL MEASURE:

In 1990, Suva introduced a new safety guard for construction site circular saws. This new safety guard, with the trade designation B90, has significant benefits over the old types of protection devices. The benefits over previous types are that it does not have to be actively positioned manually, but lowers itself to the safe position where it affords a good view of the cutting area thanks to its transparent hood. In the 10-year period since this safety guard was first put on the market, almost every saw in Switzerland has been converted, while the B90 has become standard equipment for new circular saws.

The incidence of accidents declined sharply, as the statistics show. Based on the average of the four years before its introduction (4.45 accidents per 1,000 insurees) and of the seven years after the safety guard's introduction (2.85 cases per 1,000 insurees), the decrease in accidents involving construction site circular saws amounted to around one third (Figure 2). The cost of accidents with circular saws in the construction industry dropped by 47% (Figure 3) - far more than the reduction in the number of cases.

The cost-savings can be calculated by working out the costs that would have been incurred if the same frequency levels had been maintained and by deducting the actual costs. From 1991 on, this means annual savings in direct costs of about CHF 5 million. In contrast to this, the additional investment cost - mainly for converting all the construction site circular saws already in use and estimated on the basis of all the devices sold between 1990 and 1998 - amounts to CHF 3.5 million.

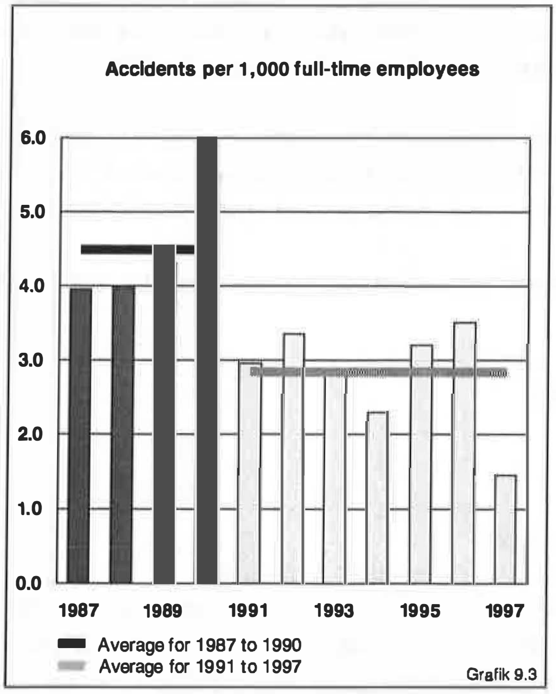


Figure 2. Frequency of accidents with circular saws

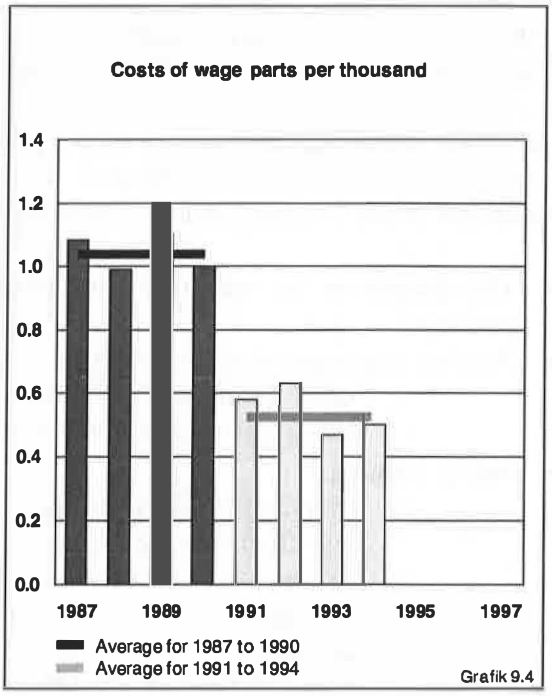


Figure 3. Cost of accidents with circular saws

EXAMPLE OF A MANAGEMENT SYSTEM IMPLEMENTED:

For the last 5 years, Suva has been actively involved in introducing occupational safety management systems among companies. Our approach is with the Suva project "Integrated safety".The project covers the following stages:

- Approaching a company with an offer of services
- Decision by the company
- Inventory (self-assessment by the company, audits by Suva)
- Plan of action by the company (taking existing systems into account)
- Management workshop with the aim of approving the plan of action
- Seminars (executive seminar, audit techniques, cause-and-effect diagram, absence management)
- Implementation with technical advice and assistance from Suva
- Final discussion (target achievement, further procedure)

How long the project lasts depends on the company's requirements. Originally, we estimated a one-year process, but we feel that 2-3 years is more realistic and sensible nowadays.

I was fortunate enough to conduct such a project in a construction company with 230 full-time employees. The project was initiated in mid-1997 and the final discussion took place in December 2000. The main changes introduced as a result of the project were these:

- The targets to be achieved were determined and then communicated to the entire personnel
- A safety organization was developed
  - Safety committee with management
  - Safety officer in a 30% position
- Safety training
  - Training the safety officer
  - Executive training with 2-day seminars
  - Foremen and chargehands were instructed in audit techniques
  - The personnel were instructed on the construction site on technical occupational safety on a case by case basis (Example: lashing loads to cranes)
  - All forklift truck drivers and machine operators were trained in relevant courses in the trade branch
- Determining safety standards
- Risk determination when submitting bids and during work preparation
- Planning of measures based on the risks identified and experience gained in the treatment of events
  - Introduction of absence management
  - Systematic evaluation of near-accidents and accidents
  - Monthly safety audit by each site supervisor together with the foreman on each construction site
- The personnel were equipped with their own personal safety bag
- First aid and emergency planning was defined for each construction site
  - Concept and training for the personnel

- Active cooperation of the personnel was ensured
  - Personnel are represented in the safety committee

The implementation of these measures had an effect 3 years after starting the project.
The following figures were given in the Annual Report for the year 2000:
The number of hours lost was reduced from 11,815 in 1998 to 3,488 in the year 2000 with practically unchanged personnel (Figure 4).
The **costs** involved comprise the following:

- The cost of personal safety equipment
- Personnel costs for the safety officers
- Personnel costs for training and audits
- External course costs for executive awareness and empowerment

For the three years under observation, these costs amounted to a total of 211,000.- Swiss francs (Figure 5).

Taking the year 1998 as ground zero, the **savings** can be calculated from the difference in the following years. This means that, in 1999, there were 2,300 fewer hours lost and, in the year 2000, there were 8,300 fewer hours lost. This makes a total of 10,600 hours, which - with an hourly rate of 50 Swiss francs - result in a total of 530,000.- Swiss francs.

In the final analysis, the actual savings are 530,000 minus 211,000 Swiss francs, making a final total of 319,000 Swiss francs.

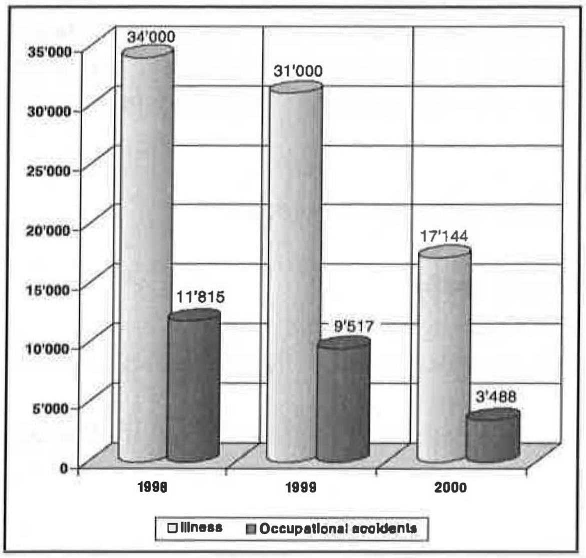


Figure 4. Hours lost 1998 – 2000

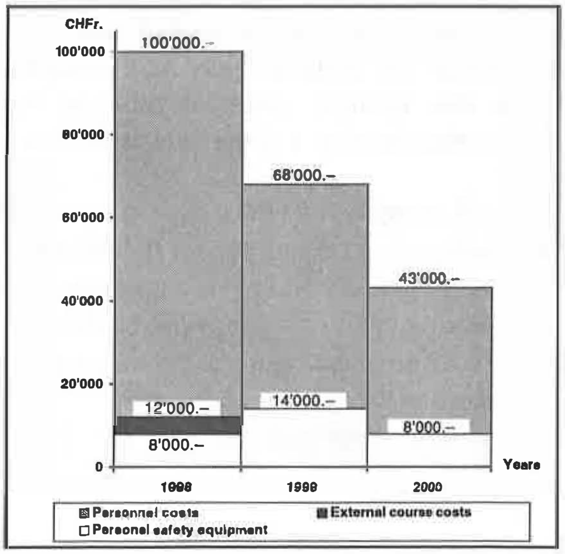


Figure 5. Costs involved

As a result of various factors such as enhancing the awareness of personnel, absence management and other factors, the number of hours lost due to illness were reduced by almost half - down from 34,000 to 17,144 - during the same period. If we give the standard hourly rate of 50 Swiss francs again, this means that there was a saving of 150,000 Swiss francs in the first year and 850,000 in the second year, resulting in a total saving of one million Swiss francs altogether.

Taking everything into consideration, the final saving was **1.3 million Swiss francs.**

Unfortunately, I do not have any figures relating to non-occupational accidents, so I am unable to comment on these at this point.

It was also evident in other projects that improvements in safety and health protection in the workplace had important synergy effects in the private sphere, thereby reducing non-work-related absences.

CONCLUSIONS:

It would undoubtedly be incorrect and even dangerous to draw conclusions for the entire working world on the basis of individual, specific cases.

Where technical measures are concerned, such as the example of the safety guard for construction site circular saws, success is achieved quickly and, in normal cases, is also lasting. However, this mainly only affects a very small, even limited area. As a result, financial success is only very modest when viewed against the general background.

With our many years of experience in implementing occupational safety and teamed with the experience gained from around 120 projects in the "Integrated safety" program, the majority of which were carried out in companies where accident risks were high, we are convinced that the benefits can only be reaped from this major savings potential when safety and health protection are systematically and consistently applied in companies. In addition, legislators have also become aware of this and issued the relevant guideline which demands that companies develop a systematic approach.

The following factors must be in place in order to have a chance of success:

- Safety must be an issue for the bosses
- Safety goals must be put on the same level as other goals
- Occupational safety may not be delegated but is a management task
- An effort must be made on a continuous basis, this means that a control system must be developed
- A new approach has to be based on a change in people's way of thinking

THE LOSS OF WORKERS' COMPENSATION PREMIUMS: THE CASE OF FLORIDA

Theo C. Haupt, Ph.D., Jimmie Hinze, Ph.D. and Richard J. Coble, Ph.D.
University of Florida
theoc@ufl.edu

A properly functioning workers' compensation system advances the goals of construction worker safety and a healthy construction industry. In addition to the natural humanitarian instincts of an employer, worker safety is promoted by the economic self-interest of employers when increased workers' compensation premiums are the price of negligence. In addition to protecting the worker, however, the Florida Workers' Compensation Act also protects construction firms from the highly disruptive effects of civil tort litigation and possible ruinous economic verdicts. The introduction to this paper briefly reviews the benefits purchased and the pro-business aspects of the workers' compensation system. It was disconcerting to encounter repeated complaints of large-scale problems due to employer premium fraud and exemptions in the construction industry which threatened Florida's workers' compensation system. These complaints issued from several reputable sources including individual contractor employers. If these complaints were accurate, the problems clearly exposed workers to potential harm and contractor/subcontractor employers to increasing vulnerability to civil litigation. The Florida Statutes confirm that the failure to secure workers' compensation insurance is deemed an immediate danger to public health, safety, or welfare. This issue is significant for those concerned with worker safety and a healthy construction industry. This study attempts to quantify the magnitude of the loss of workers' compensation premiums in Florida. The results should be a caveat for the impact of this problem on construction wherever it is practiced.

Keywords: workers' compensation premiums, premium fraud, exemptions

INTRODUCTION

A viable workers' compensation system is critical to Florida's construction industry. Conceptually the Florida Workers' Compensation Act effective July 1, 1935 [1] is a contract written by the Florida Legislature and incorporated into every employer/employee relationship. Employers gain immunity from the highly disruptive effects of civil tort litigation and the potentially disastrous economic verdicts in severe injury cases. Additionally, the employer gains freedom from any payments at all for the "non-economic" consequences of injuries such as the injured worker's losses due to pain and suffering, inability to lead a normal life, loss of consortium, and other such expensive general damages awardable under tort law. Further, even as to the economic damages resulting from significant injuries, the employer gains the advantage of a system of limited loss-of-earnings payments, far below the real long term lost earnings amounts typically proven in civil lawsuits. On the other hand, workers gains "no-fault" coverage if they can show that their injuries arose out of and in the course of employment covered under the Workers' Compensation Act. If so, workers then obtain a system of benefits including three primary parts: a limited schedule of loss-of-earning payments, medical care, and attorney's fees if litigation against the insurance carrier becomes necessary and if the injured workers are correct and prevail.

Florida's Workers' Compensation system has been the subject of many complaints and repeated legislative amendments in the past 10 years. In the construction industry, many complaints were about the issue of employer fraud. In 1997, the Fourteenth Statewide Grand Jury was convened to investigate four areas of insurance fraud committed within Florida, one of which was workers' compensation employer premium fraud. The "First Interim Report of the Fourteenth Statewide Grand Jury" issued in January of 1998 is an exemplary base work on this subject and should be fully read.

Dishonest employers through many schemes perpetrate workers' compensation insurance premium fraud. The most common include (1) failure to buy workers' compensation insurance at all, (2) obtaining fraudulent premium amounts by under-reporting payroll, by misclassifying employees, and by misrepresenting experience modification ratios, and (3) fraudulently claiming exempt status.[2] Honest employers in Florida's construction industry have testified that fraud is "rampant, and it's out there everywhere"[3] and is "monumental and getting worse"[4]. Honest employers strongly and properly complain that they are placed at a severe competitive disadvantage in bidding for work and selling their services. Obviously, fraudulent employers who do not pay workers' compensation premiums can always underbid and undersell their legitimate competitors. Further, by failing to pay the cost of workers' compensation, fraudulent employers can afford to pay higher salaries and corruptly lure away honest employers' better workers, albeit without offering compensation coverage. Further, as honest employers are either driven out of business or join the ranks of the dishonest and stop paying correct workers' compensation premiums, the workers' compensation insurance premium rates for the remaining honest employers increase.

From 1997 through 2000, the 33 to 36 field investigators of the Bureau of Compliance cited 12,239 employers for failure to have any workers' compensation insurance at all. However, this statistic only provides some quantification of those dishonest employers involuntarily caught and those committing the fraud of failing to buy any workers' compensation insurance.[5] It does not account for those dishonest employers who escaped detection. Further, it does not account at all for those dishonest employers obtaining fraudulent premium amounts by under-reporting payroll, by misclassifying employees, by misrepresenting experience modification factors, and by committing exemption frauds.

Honest employer contractors, of course, also complain that the workers' compensation premium rate in the construction industry is too high. Are the honest employers' complaints valid? Is insurance premium fraud by dishonest employers in the construction industry "rampant" and "massive"? While the available information many authorities provides pieces of evidence that support these complaints, there was no broader study to confirm or negate the asserted magnitude of the problem in the construction industry. With relatively small effort, it is likely possible to collect a number of anecdotal examples of abuses by individuals within any group in the workers' compensation system. However, such examples provide a sure basis only for criminal prosecution against the specific identified individuals. For the larger arena of intelligent legislative action, data of a much larger scope about the construction industry is required. With these thoughts in mind, it appeared important to develop data concerning the loss of workers' compensation premiums in Florida's construction industry as a whole.

THE VALUE OF CONSTRUCTION

The primary objective of this study on workers' compensation in the construction industry in Florida was to establish an approximation of the magnitude of the underpayment of workers' compensation insurance premiums. The U. S. Census Bureau prepares one of the most reliable measures of the volume of construction. Every five years, the Census Bureau conducts a census of the construction industry. The data reported for 1997 reliably estimates the total volume of construction in Florida to be $50,173,812,000. This amount takes into account all construction work, permitted or otherwise. Further, it also includes all work subcontracted out to others, work done in several other states, work done on federally owned projects, and a percentage for profit and overheads. Some appreciation, therefore, for the annual volume of construction work undertaken in Florida is pivotal to understanding the extent by which the system is defrauded each year through premium losses.

To arrive at the value of construction from the census data some adjustments needed to be made. Several construction firms based in Florida claimed for work done in other states, primarily in Georgia, North Carolina, Texas, and Alabama. It follows that the volume of construction work in Florida needed to be decreased somewhat to account for the value of this work. The value of this work was 4.80% of the value of total construction. Additionally, contractors from Texas, North Carolina, Georgia and Alabama worked in Florida. The value of this work was 3.01% and is to be included in the total value. These calculations are set out in Table 1.

These percentages were assumed to have been applied uniformly across all types of construction. It was therefore necessary to adjust the values in the census by these same percentages. The resultant values of residential and non-residential construction are:

Residential: $14,465,177,000 - ($14,465,177,000 * 4.80%) + ($14,465,177,000 * 3.01%) = $14,206,250,332
Non-residential: $49,275,768,000 - $14,206,250,332= $35,069,517,668

Table 1. Calculation of the value of construction in Florida in 1997 ($1,000s)

Value of construction in Florida from census	$50,173,812	
Less work done in Alabama, Georgia, North Carolina, Texas	($2,408,916)	4.80%
Adjusted value of construction	$47,764,896	
Add work done in Florida by contractors from Alabama, Georgia, North Carolina, Texas	$1,510,872	3.01%
Adjusted value of construction	$49,275,768	

CONSTRUCTION LABOR COST

To determine workers' compensation premiums, the labor portion of the total cost must be identified. The premiums are determined by and related to the labor content of construction projects and not the total value of construction. It is possible to approximate the total amount of premiums that should be generated by using total construction revenue figures in a given year. However, this approximation will only be meaningful once the relationship between labor cost and total construction cost has been established. In other words, the percentage proportion that labor costs makes up of total construction cost has to be determined.

By using construction bids, estimating guides and contractor surveys, it was possible to establish labor cost as a percentage of total building cost in Florida. However, each of these methods yielded slightly different results for each of the types of construction.

Residential Construction

Method 1

In a recent study, an actual residential single family structure constructed in 1997 in Florida was used to calculate the labor content of residential construction projects.[6] Using the results of this calculation, the workers' compensation premiums on residential projects were estimated. The labor content of the project was 39.6% of the total net bid, and 28.6% of the total gross bid. The workers' compensation premium for the project represented 7.55 % of the total gross building construction cost.

Method 2

In that same recent study, the data, based on information provided by Robert Mewis, the Chief Editor at R.S. Means Engineering,[7] was used for an average 2-story house with a living area of 2,000 square feet. The labor content was calculated to be 46.54% of total net cost, and 43.51% of total cost including overhead and profit. By applying the same workers' compensation premiums to the estimated labor costs for each component, a composite workers' compensation rate of $28.57 per $100 of payroll was determined. This rate represented 13.29% of the gross costs of construction for a typical residence.

Method 3

The labor costs associated with a typical (three bedroom, two-bath) residence were calculated using the cost data for residential construction from Means[8] to determine the costs of the various cost components. Since the labor costs were isolated in the Means guide, the workers' compensation rates were applied to the estimated labor costs for each craft. This resulted in the derivation of a composite manual workers' compensation rate of $24.56 per $100 of payroll, which represented 6.97% of the gross costs of construction for a typical residence. The labor content was calculated to be 28.38% of total gross costs.

Method 4

In order to establish the percentage labor content of residential construction, a representative sample of 200 contractor members of the Association of General Contractors (AGC) was surveyed. However, only 55 of those AGC members agreed to participate in the study. Of these, 11 were residential contractors. The mean percentage labor content of residential construction reported by the contractors in the sample was 42.95% of total cost.

Non-Residential Construction

Method 1

In an earlier study,[9] labor cost estimates were determined for commercial construction using an actual schedule of values from a small commercial project constructed in Florida in 1997. The labor content of the project cost was calculated to be 35.71% of total cost including overhead and profit, and 43.15% of total net cost.

Method 2

In order to establish the percentage labor content of non-residential construction, a representative sample of 200 contractor members of the Association of General Contractors was contacted. Of the 55 AGC members who agreed to participate in the study, 52 engaged in non-residential construction. The frequency distribution of labor content by type of non-residential construction is depicted in Table II.

Table II. Labor content % of gross cost by types of non-residential construction undertaken

	Commercial	Heavy Industrial	Light Industrial	Other
Mean (%)	36.3542	31.0625	33.9444	34.4000
Median (%)	39.5000	30.0000	30.0000	40.0000
Std. Deviation	16.8349	13.2191	21.2462	18.6896

For commercial work, the construction mean percentage labor content was 36.35% of total cost. For heavy industrial, the construction mean percentage labor content was 31.06% of total cost. For light industrial, the construction mean percentage labor content was 33.94% of total cost. For other types of non-residential construction, the construction mean percentage labor content was 34.40% of total cost. The mean (non-weighted) percentage labor content was computed to be 35.30% of total cost for all types of non-residential construction.

WORKERS' COMPENSATION PREMIUMS FOR FLORIDA IN 1997

The computation of the total amount of workers' compensation premiums is not a simple task as the manual rates vary considerably between different crafts. Since the details of this information are not known or cannot be readily extracted from a known database, an attempt was made to derive a composite workers' compensation rate.

By applying known manual rates for various crafts in Florida in 1997 to the commercial project example used in the Coble and West study,[10] the workers' compensation insurance premium as a percentage of total labor cost was computed to be 17.70%. The workers' compensation insurance premium as a percentage of the total gross cost was computed to be 6.32% and as a percentage of total net cost to be 7.64%.

Means [11] provides extensive data on workers' compensation insurance premiums as an average percentage of both labor and total gross building construction cost. According to this data, the national overall weighted average workers' compensation insurance premium as a percentage of total labor cost for all types of construction projects is 19.95%. The published data indicated the average manual rate per $100 of payroll to be 29.3% for the State of Florida for commercial construction in 1997.[12]

In the Coble and West study, the derived labor percentage of 35.71% and the 29.3% of labor cost for workers' compensation premiums in the State of Florida[13] were used. The calculation produced the workers' compensation premium rate for commercial construction of 10.46%.

These derived workers' compensation premium percentages were applied to the total dollar volume of construction in Florida to provide an estimate of the total workers' compensation premium that should have been generated and collected. For the purposes of this study, all experience modification ratios (EMRs) were considered 1.0. The workers' compensation premium for any particular sector of the construction industry could then be computed by multiplying the total value of that sector by the applicable percentage workers' compensation premium rate.

The difference between the total amount of workers' compensation insurance premiums collected by the different carriers, or placed in escrow by self-insurers provides an indication of the magnitude of premiums losses through fraud and exemptions.

PROJECTED PREMIUM VALUES

The overall analysis of the data has led to the development of several values that reveal the percentage of overall costs represented by workers' compensation premiums. Since Means [14] utilizes union pay scales and this is not consistent with practice in Florida, the resultant premiums needed to be reduced by the percentage by which unionized wage rates exceeded those actually paid. These rates were estimated to be about 66% of those used by Means.

Table III. Calculation of workers' compensation premiums due in Florida for residential construction

Residential Construction Volume	Derived W.C. Rates	Premiums Due	Adjusted Premiums Due
$ 14,206,250,332	6.97% (Method 3)	$990,175,648	$635,515,928
$ 14,206,250,332	7.55% (Method 1)	$1,072,571,900	$707,897,454
$ 14,206,250,332	13.29% (Method 2)	$1,888,010,669	$1,246,087,042

The calculations to estimate the value of workers' compensation premiums for residential construction that should have been paid in the State of Florida are reflected in Table III.
The derived workers' compensation premium rates for commercial construction were assumed to be appropriate for use for all types of non-residential construction and are used. The calculations to estimate the value of workers' compensation premiums for non-residential construction that should have been paid in the State of Florida are reflected in Table IV.

Table IV. Calculation of workers' compensation premiums due in Florida for non-residential construction

Non-Residential Construction Volume	Derived W.C. Rates	Premiums Due	Adjusted Premiums Due
$ 35,069,517,668	6.32% (Method 1)	$2,216,393,517	$1,462,819,721
$ 35,069,517,668	10.46%	$3,668,271,548	$2,421,059,222

The projected total workers' compensation premiums, including residential and non-residential construction, that should have been collected in Florida range from on the low end to $3,667,146,263 on the higher end for all types of construction.

OBSERVATIONS

The National Council on Compensation Insurers (NCCI) reported that $912,244,160 was collected in workers' compensation insurance premiums for all construction related work.. This value is significantly different from the range of $2,116,335,649 to $3,667,146,263 as determined by this study. The difference of between $1,204,091,489 to $2,754,902,103 provides a reliable estimate of the premiums that were not paid into the system due to fraud or exemptions.

In the construction industry, estimating is a common and reliable practice. Most of the values used in this study were based on estimates and approximations. But the estimates are conservative due to the conservative nature of the data used and the assumptions made. For example, the values recorded for building permit purposes commonly understate the actual higher dollar amount of construction work involved. Further, in the examples or case studies used, the experience modification ratios (EMRs) were all considered being 1.0. Generally EMRs are higher than 1.0 with a resulting higher premium due. Premium fraud is likely as firms seek to be assigned lower EMRs than are required based on the firm's actual claims history. Additionally, to the extent that there are under-reported payrolls or cash-under-the-table payrolls without the payment of social security taxes or withholding taxes, there would likely also be a failure to voluntarily report these matters to others. This again would result in undervalued conservative data available for this study.

The mathematical mid-point figure of the measurable range of magnitude for lost premiums is $1,979,496,796 in lost premiums. However, the average of the residential construction volume methods for adjusted premiums due plus the average of the non-residential construction volume methods for adjusted premiums due is $2,811,106,279. That total less the premiums collected provides the lower figure of $1,405,553,140 in lost premiums. Due regard must be given to the overall conservative approach of this study, even while also acknowledging the understated nature and use of the data involved. Putting together all of these factors and all of the information obtained during the course of this study and the earlier Coble and West study, the conservative magnitude of loss of workers' compensation premiums in 1997 due to employer fraud and exemptions in the Florida construction industry exceeded $1,3 billion.

CONCLUSIONS

The conservative magnitude of loss of workers' compensation premiums in 1997 due to employer fraud and exemptions in the Florida construction industry exceeds $1,3 billion.

While it is anticipated that future studies will produce more data to yield more refined measurements, it is evident that the measured range of between $1,204,091,489 to $2,754,902,103 in lost premiums demonstrates a very serious gap between collected premiums and the amount that should have collected. Uncollected premiums arise due to several probable causes. The major causes include:

- workers' compensation exemptions;
- working without workers' compensation insurance;
- deliberate misclassification of employees;
- under-reporting payroll; and
- misrepresenting experience modification ratios (EMRs).

The findings of this study show that more money in workers' compensation premiums was lost than was collected. Further, they support the honest employers' complaints and the dire warnings of the Fourteenth Statewide Grand Jury that this problem "will undermine the entire workers' compensation system and threaten its collapse". The problem is a very serious one demanding of swift intervention.

While this study endeavored to derive the magnitude of the problem of loss of workers' compensation premiums in Florida, it is likely that wherever workers' compensation systems exist, there will be contractors that will gain unfair competitive advantage through non-payment or underpayment of workers' compensation premiums. The consequences of these undesirable management actions include increased premium rates, exposure of workers to harm and contractors and subcontractors to increased vulnerability to civil tort litigation.

REFERENCES

[1] Florida Department of Labor & Employment Security, Division of Workers' Compensation. History of Workers' Compensation in Florida (2000).

[2] 14th Statewide Grand Jury Interim report at pages 8 through 22.

[3] Testimony of Russell Budd, president of Wall Systems, Inc., at the Department of Insurance 1999 Rate Hearing, transcript p. 128.

[4] Testimony of Kathleen Bailie, owner of Bonness, Inc., Pavement and Stone Contractors, at the Department of Insurance 1999 Rate Hearing, transcript p. 140.

[5] Division of Workers' Compensation Annual Reports 1997 to 1999 and Bureau of Compliance Summary of Enforcement Activities: Statewide Month to Month

[6] Coble, Richard J. and West, James L. (2001): "The Cost of Workers' Compensation Fraud and Exemptions in Residential and Commercial Construction in the State of Florida," Construction Education Concepts, Gainesville, Florida.

[7] R.S. Means (2001): *2001 Residential Cost Data*, 59th Annual Edition, Kingston, Massachusetts.

[8] R.S. Means (1997): *Building Construction Cost Data*, 55th Annual Edition, Kingston, Massachusetts.

[9] Coble, Richard J. and West, James L. (2001): "The Cost of Workers' Compensation Fraud and Exemptions in Residential and Commercial Construction in the State of Florida," Construction Education Concepts, Gainesville, Florida.

[10] Coble, Richard J. and West, James L. (2001): "The Cost of Workers' Compensation Fraud and Exemptions in Residential and Commercial Construction in the State of Florida," Construction Education Concepts, Gainesville, Florida.

[11] R.S. Means (1997): *Building Construction Cost Data*, 55th Annual Edition, Kingston, Massachusetts.

[12] R.S. Means (1997): *Building Construction Cost Data*, 55th Annual Edition, Kingston, Massachusetts.

[13] R.S. Means (1997): *Building Construction Cost Data*, 55th Annual Edition, Kingston, Massachusetts.

[14] R.S. Means (1997): *Building Construction Cost Data*, 55th Annual Edition, Kingston, Massachusetts

THE IMPACT ON SAFETY OF THE VISIBILITY OF THE COST OF PREVENTION

Joos Louage
Comite National d'action pour la Securite et l'Hygiene dans la construction, Belgium
cnac@cnac.be

In order to reflect on the transformation of the European directive 92/57 into a Belgian law, a study group was set up. As safety costs were at the time categorized under the general costs of the contractor, they were not visible in the contractor's offer and there was no guarantee for the client that preventive measures had actually been taken.

So, the study group suggested to make the price of preventive measures visible in the offer. In practice, the coordinator at the project preparation stage has to draw up a safety and health plan, stating risks and required measures. Offers of contractors must mention detailed prices of the measures that will be taken in order to follow the S&H plan.

Evaluating cautiously the work of the coordinators following the new legislation, we see that minor clients often miss out a bit. However, if we manage to follow the correct implementation of these new regulations thoroughly, we are convinced that we will soon be able to present the positive effects of the new legislation.

Belgium has finally succeeded in transforming the European directive 92/57 into a Belgian law. It is operative since May 1st 2001, merely a few months ago.
A first attempt was made in 1999 and failed, partly because the texts, out of precipitance, showed quite a bit of lacunae, partly because the Council of State pronounced the text unlawful by reason of procedure.

"THE BRAINWORK"

When reviewing the texts, fundamental brainwork was mainly done by the building contractors: why is the building industry so unsafe, why do we talk so much about security, doing so little about it in practice.

When talking about cars, safety is one of the principal sales arguments, or even the main argument, whereas in our sector, security is not even discussed with the client, let alone that it would be used as an argument.

OBSERVATIONS

Those were the conclusions after the brainwork:

1) The positive effect of safety at work is usually very hard to demonstrate. Proving that an accident did not happen thanks to the preventive measures that were taken would be a reduction ad absurdum proof.

2) For a building contractor, safety at work counts as immediate expenses: safety equipment, training for the personnel etc, whereas its effect can only be measured in the long term (e.g. a decrease of the cost of insurance).

3) In the present legislation, safety at work is indeed obligatory, but the safety costs are categorized under the general costs of the contractor.

   This situation has two very important consequences:

   a) The price does not show the client whether or not the contractor has calculated in a safety budget. If he has not, he has of course a good chance to be less expensive than his colleague who has.

   b) When the work is finished, the client pays the sum that was stated in the contract, regardless of what the contractor spent on preventive measures; his profits will raise as he saves more on safety.

According to the study group, this pernicious mechanism in which insecurity is first a weapon in the competitive struggle between contractors and then a way to increase profits, was a predominant cause of many construction accidents.

CONCLUSIONS

So, the study group suggested to make the price of preventive measures visible in the offer of the building contractor.

Yet I must add, in all fairness, that whereas everyone - contractors, clients, authorities,... - agreed to the conclusions of the study group, almost no one was willing to accept the solution that had been suggested. It took several months to convince everyone, or a sufficient number of people anyway, that the measure that had been suggested was logical, simple and workable.

EXECUTION

How was this principle transformed into the legislation on Temporary and Mobile Construction Sites?

1) The coordinator at the project preparation stage draws up the safety and health plan of the construction site, describes the different risks and completes the plan with a quantity surveying of the preventive measures that are required. This document is an integral part of the construction specifications of the project.

For example: exactly like the architect describes the false ceiling and writes it down in the quantity surveying, the coordinator describes where the safety nets must be installed during the execution stage and what the minimum required characteristics are.

2) With the offer of the building contractor goes a document in which he explains how he integrates the safety and health plan with his work, and he mentions detailed prices in the quantity surveying that was drawn up by the coordinator at the project preparation stage.

3) The last task of the coordinator at the project preparation stage is to advise the client on the way the different contractors have integrated security with their offer.

4) Since the preventive measures are part of the quantity surveying, the contractor is only paid for the preventive measures he actually takes.

   For example: if he installs 200 m2 of safety nets, he will be paid for installing 200 m2; if he does not install any safety nets, neither will he be paid for it. Thus, taking risks is no longer financially rewarded.

FIRST EVALUATION

At present, it is of course still premature to come up with results. The implementation is still in an intermediate stage that will end November 30th.
However, we can make a first evaluation of how the coordinators at the project preparation stage do their part of the job. We see that some important clients apply the rules concerning the visible cost of preventive measures correctly, whereas others try to get away with it with minimal effort, stating one global sum for the whole of the measures. The new regulations did not get through to minor clients yet. They still fear that things will become more expensive, now that they can see in a separate item of the quantity surveying what they pay for the security of the workmen.

CONCLUSION

We are convinced that a correct application of this new legislation will have a positive influence on the accident rates in Belgium. It will, however, be necessary to follow the correct implementation of these new regulations very thoroughly and to demonstrate, on the basis of the first measurable results, that things have indeed entailed a positive effect.

THE VISIBLE AND HIDDEN COSTS OF NON SAFETY (THE NONEXISTIENT SAVING)

Valentin de Torres-Solanot y del Pino
General director of COPREDIJE CORP. Madrid, Spain
copredije@nexo.es

This report proposes a study that will try to demonstrate that one of the belief more common among great quantity of managers of small and medium companies and also among professionals of the construction sector that is to consider the expenditure dedicated to the Prevention of Labour Risks and/or security as an expense that one can and should avoid becoming a part that one can add to the benefits.

This will not be done in a rigorous way but rather as a deep remark based on data and real facts showing the necessity to change the mental concept in this sector.

The final conclusion is that it results cheap to invest in safety, because its results are extremely profitable for both the company betting on Safety and Health, but also for Society in general.

INTRODUCTION

Ladies and Gentlemen members of the congress please allow me to do a previous comment I use for the construction students that attend my classes on Safety and Health. They all know that there is in Spain a strong tradition that consists, for the individuals and the companies, in buying the Christmas Lottery at the end of the year. The tickets are usually shared, being divided in tenth. Everyone participates with the hope to win the kitty, on the other hand, in the construction works where the work is done in an insecure way, disobeying the existing norms of safety, lottery is played every day with the hope that the pot won't fall, and if it does praying that it will be for the works next door.

Now then, going back to my subject, I wish to make a review that maybe some of the assistants of this international conference will find lacking of scientific rigour, but I have preferred not to make excessive use and abuse of data, charts and diagrams in the idea that many others of the lecturers would make it this way it and my desire is to be the less repetitive as possible.

Antecedents: since the introduction in the projects of a document that quantified the economic part dedicated to Safety and Hygiene, without considering these elements as an integral or intrinsic part for the correct execution of the units contemplated in them for the realization of the works. It arose in the mind of some technicians and managers of the construction sector that a mattress or a sack that muffled the shocks in which could enter accidental costs had appeared, because independently of the use or not of the part dedicated to Safety and Hygiene, you would get paid in its integrity.

Due to this fact, the control lack on this item that was relegated on a second, when not on a third plane, as well as the lack of rigour in its programming, acquisition and employment, always subjected to the interests of the production, the term, the budget and the quality.

In the end, what was valued was to have cashed the whole item and to have wasted the less possible of this one, but with at the same time without any serious or lethal accident taking place in the work (they would only occur if we had bad luck) the certain thing is that systematically the lottery was played every day.

This concept completely erroneous, along with the widespread ignorance of other antecedent causes "The cause of 60% of the fatal accidents in the works comes from decisions adopted before the beginning of the works!" (Official publications of the European Communities, Safety and Health in the Construction, 1993) with respect to the fatal accidents in Europe in the year 1988 and that generates the concept in the directive 92/57 / EEC of the figure of the Coordinator of the Design and of the Work.

Unfortunately, and although many years have passed, there are still some persons and I refer to the promoters in general that have not assimilated the concept that a risk not detected on time triggers a more important cost that the cost of prevention, not giving a bigger importance to the fact that safety is not really integrated in the project at all levels, thinking that the main problem during the execution of the work is that what arises in each moment has to be solved.

This is no surprise then that later on during the work the tendency that imposes itself is the previously described item-mattress.

All of us know more than enough the works carried out by H.W. Heinrich in 1931 and of Frank. E. Bird with their bringing up to date of 1969 and their classification in direct and indirect costs, that of Simonds with the assured costs and non insured or that of the production elements that contemplates inside each factor of production manpower, Machinery, Materials, Facilities and Times, as well as the existence of other methods of calculation of costs based on the previous ones.

At the end what happens most of the times is that the decisions taken will be based on economical aspects and if the departure data for their study are not real, making the correct decision will be complicated, I will permit myself to use the diagrams that appear page 100 of Technics of Prevention of Labour Risks (José María Cortes Díaz, 1998), not specific of construction but of industry and let consider the Fig.1 RELATIONS ACCIDENTS COST–PREVENTION COSTS and the Fig.2 LOGARITHMIC DIAGRAM PREVENTION COSTS – ACCIDENTS COSTS–PERCENTAGES OF RISKS REDUCTION

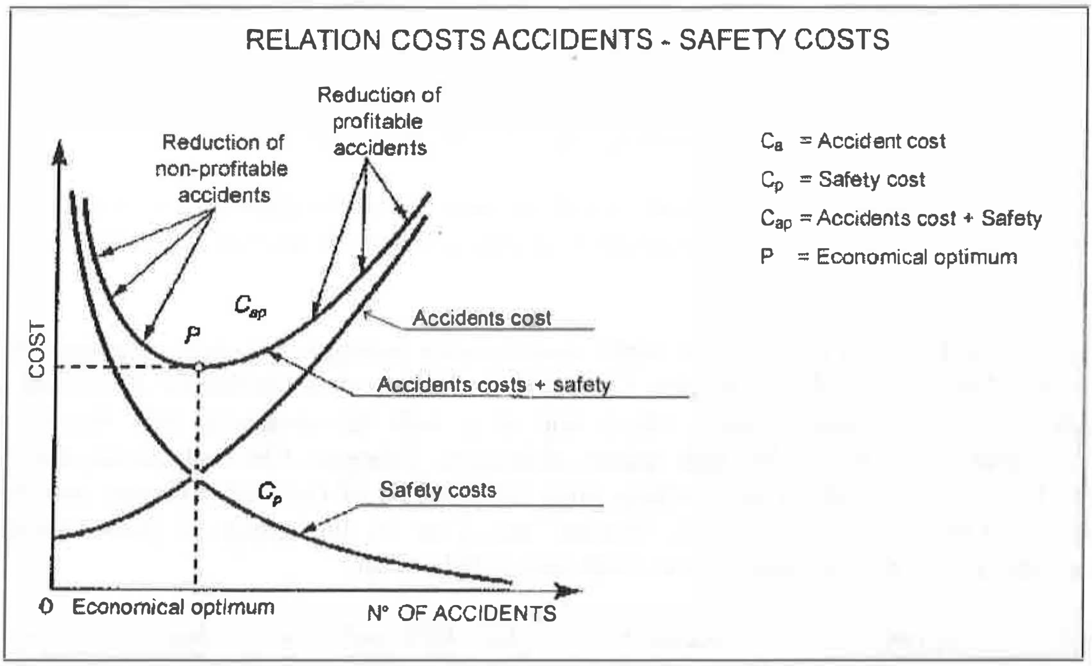


Figure 1. Relations accidents cost-Prevention costs

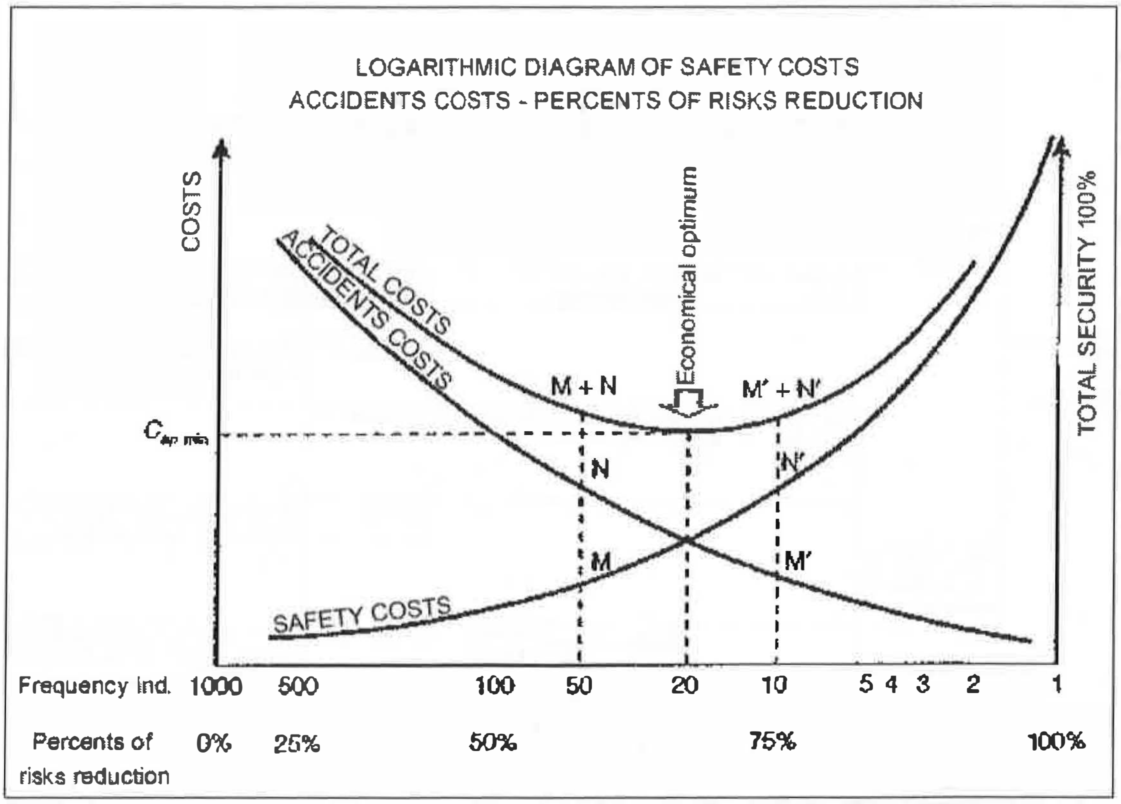


Figure2. Logarithmic diagram prevention costs – accidents costs–percentages of risks reduction

Now then, contrary to what happens in the industry, in construction we encounter two perfectly defined control chains, the one corresponding to the Promoter (that takes charge of the work) and that of the Manufacturer (Contractor that executes the same one), as well as a multiplicity of secondary actors: Subcontractors, Autonomous and Suppliers.

As we see, the matter is more complex when the time comes to attribute which will be the visible and the hidden costs of the non safety, and in which proportion all the interveners will be affected.

Leaving of the base that the accident victim won't usually belong to the chain of control of the Promoter (Director, auxiliary Director, Coordinator, Technical Assistentence of control and surveillance, geotechnics, quality, etc...) and if it will be somebody that this in the manufacturer's line, not in the high sphere, (Manager, Delegate, Chief of Group, Chief of Work, Chief of Production) but starting from the position of *General Foreman* and down (Foreman, Official 1ª, Official 2ª, Worker, etc...) or in the group of Subcontractors, Autonomous, Suppliers or Suppliers we will deal with later on.

Simplifying, supposing that the accident takes place followed by a sick-leave, for a worker that belongs to the Constructor's team and that he is not an intermediate control but rather below the one in charge, we can see that the decisions taken by the work Chief in this respect appears in the P. 66 of Planning and execution of Prevention (Cesar Mínguez Fernández and other, 1996) Fig. 3

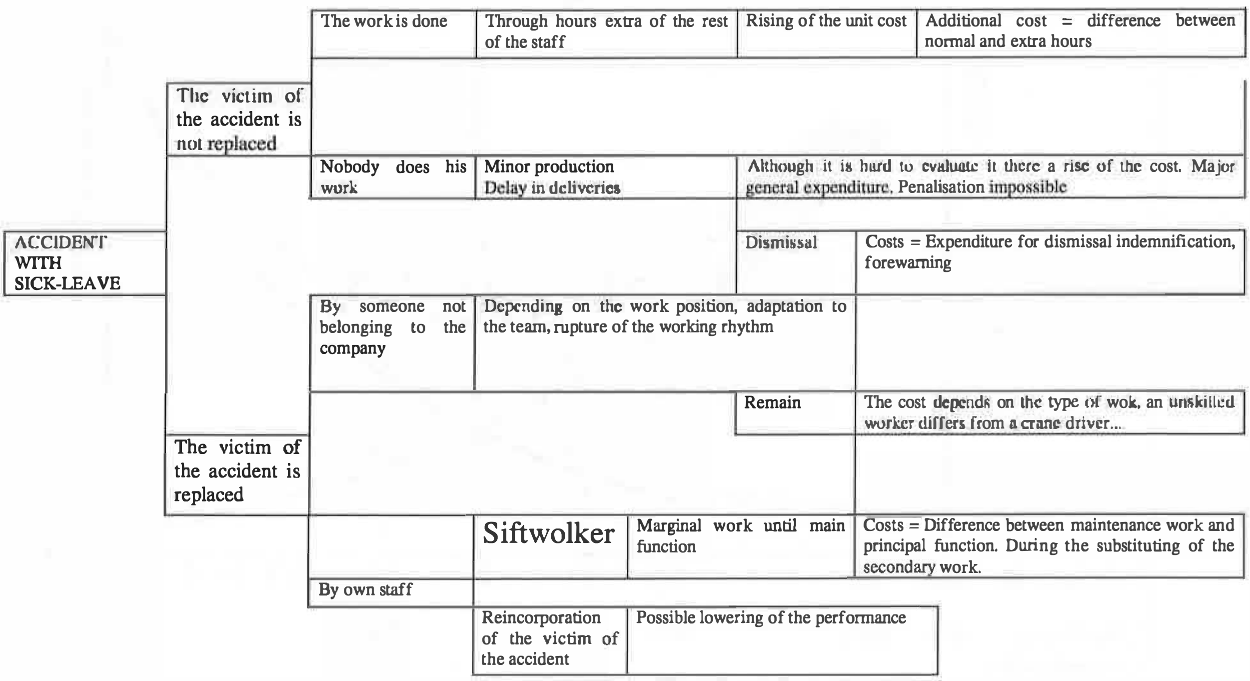


Figure. 3

We can already see the quantity of possibilities and dilemma that arises in this simpler case, but that happens if it is a fatal accident that takes place is in the figure of a subcontractor, autonomous, Supplier or Supplier?.

EXPERIENCE

The case that I will expose next is based on a real fact of these characteristics in which one can see how complex can be a situation and the difficult thing it can be to quantify the costs.

Fatal accident that affects a worker subcontracted by a subcontractor and leaves his partner wounded.

An auxiliary machine intervenes, with mechanical, electric and computer components that was rented to a firm of machinery rental.

The climatologically situation of that day was of high temperatures, superiors to 35 degrees.

The workers were informed on the handling characteristics of the machine in question and they wore their own equipment of individual protection, although in the case of one of them (the deceased) according to the witness, he wore it although no elements of a supposed failure could be found, and in the other one its use was decisive to avoid bigger consequences.

Once produced the accident the following facts took place:

RESULTS

All the works of the work were paralysed, warning was given, not necessarily in the order here exposed to people responsible for the company manufacturer, to the manager of the affected workers, to who had subcontracted them, to the Coordinator regarding Safety and Health, to the Promoter, to the competent Labour authority, to the authority, to the Judge, to the services of Emergency, etc...

The area in which the accident took place was condemned, during one month, as much this as the machine that it was implied in the event were sealed awaiting the verdict of an independent expert in this respect. Meanwhile no one can work in that place, fortunately it is not a vitall area for the work, if so the costs would raise extremely.

During some days no one worked in the work, later on works was started partially in other parts, but meanwhile we will analyse the chain of events that took place and that affected a great number of instances, companies, technicians and workers.

The machinery of the Administration of Justice put into operation through the Judge that intervened in the case (alone it is the beginning of the judicial costs), the machinery of the Labour Authority began its work through the Inspector of Work and began to require great quantity of information, documentation, etc..., all those affected communicated their insurance the fatal accident.

The insurance companies came to the place of the event to elaborate the corresponding report and to expect what could happen next.

The Mutual companies to which belonged those affected who subcontracted them and who hired their contractors displaced their technicians to carry out a brief investigation of the accident.

The technicians of the contractor's prevention made the same thing, along with the group Chief and the Delegate, getting informed through the company.

The work Head came after one day in the work and informed the Promoter of the unfortunate event and of the performances that were being carried out.

The Coordinator regarding Safety and Health, as soon as he was warned, went to the work two hours after the event, warning his superiors as soon as he knew about it and activating the system foreseen for serious and fatal accidents moving to the place a team of investigation of accidents made up of four people with proper material to carry out that type of work, being the superiors and Directive in permanent contact with the Coordinator and the investigation team.

After numerous meetings, and once an agreement reached between all the parts, the recruiting of an independent and qualified Expert that was done, that will decide the verdict mentioned previously.

How can it be seen in the previously exposed case, based as I have indicated on a real fact, if the direct costs according to some theories, insurable according to other maybe could be determined somehow, but : Can we say the same of the indirect ones or those not insurable according to the case?.

Following the line of some hypotheses that are not true but that could be in other circumstances, what would happen if the accident take place in the only access point and non substituible of the work, and if the affected subcontractor was the owner of a microcompany of 4 workers that disappears after his death, if he was the head of a family with three small children only depending on his source of revenues.

The above-mentioned is not complete fiction, in fact it is quite common in the construction sector, and I would like now to make some reflections in this respect.

DISCUSSION

What selection approaches did the Promoter follow when selecting the construction company and when giving it the work? Were the risks that caused the accident they considered in the Project? Who was designed by the Construction Company as the work Chief and what criteria were followed for the selection of the subcontractors?, Were the workers informed and formed to carry out the works that were commended?, Were the machines and tools the appropriate ones and were they correctly maintained?, Did the Technician of Prevention of the Construction Company and the Coordinator Fulfil their obligations as regards Safety and Health? ... and mainly could the accident and its consequences have been avoided?

Undoubtedly, if one meditates a little in all the above-mentioned questions, he will realize that many times what lacks is that will of change, bearing the mentality that instead of speaking of costs, to speak of Investments (NO TO THE COST YES TO THE INVESTMENT) that is the idea that really helps saving, lives, resources, time, money and mainly an improvement for Society as a whole. The summary is that Prevention as a means and an end invites to participate of the same one with all the tools within our reach among those that find the Coordination as a Procedure, and the three c's, Collaboration, Convincing and Knowledge.

CONCLUSION

Some saving has really existed for not completing correctly the established and for getting paid for something that or was not acquired, or was not distributed, or was not informed, or was not made, or was not used, or was not used correctly, evidently not, then what saving are we speaking about? of the nonexistent saving.

For this reason, it is a lot more convenient, from the conception of the project, including safety as an element fully contemplated and incorporated in all its phases, avoiding that high percentage that said at the beginning, pass from 60% to 0% if it is possible and during the execution of the work we look for the measures, the springs and the means so that one can work under the best conditions of safety that allow to carry out the work and otherwise think of other alternatives to the same work.

Many times the solution doesn't go to make what was foreseen when you began to conceive the project, but rather it is necessary to toss imagination in the search of alternative solutions to the same project, since when integrating safety in its design it can be that you varied the initial idea totally, the new proposal being in the course of time more profitable than the insecure one.

Finally, and although at the beginning it is not completely evident, it is a lot more profitable to invest in Prevention, mainly for the one that use Safety and Health as for Society in General.

REFERENCES

[1] Commission of the European Communities (1993) Safety and Health in the Construction (Office of Official Publications of the European Communities), Brussels, Luxemburg.

[2] Caesar Minguez Fernández, Eusebio Cermeño Monge, Manuel Castro Sánchez, Antonio Roldán Calderón, Rodolfo Albiñana Pérez, (1996) in Planning and Execution of Prevention (Editorial Service of Formation of Constructions LAIN, CORP.) P. 66, Madrid, Spain.
José María Cortés Díaz, (1998) in Technical of Prevention of Labour Risks (Editorial Tébar) P. 100, Madrid, Spain.

[3] Valentin de Torres-Solanot del Pino (1999) in Manual of Procedures of Coordination Vol. I (COPREDIJE CORP. Publisher) diverse Pages, Madrid, Spain.

[4] Valentin de Torre-Solanot del Pino (March 1999) in the Monitor number 1812 (Publisher National Grouping of Manufacturers of Works) P. 45, Madrid, Spain.

THE COSTS OF NO SAFETY IN THE BUILDING SECTOR AND THE BENEFITS STEMMING FROM THE ADOPTION OF THE QUALITY/SAFETY INTEGRATED MANAGEMENT SYSTEMS

Pasquale Finelli , Adriano Maggi
INAIL – Technical Consultancy for the Building Sector, Rome

Maria Pacciana
INAIL – Central Direction for Prevention, Rome
m.pacciana@inail.it

In Italy – as in Europe – the building sector records the greatest number of industrial accidents and diseases of all the productive sectors.
According to statistics by INAIL (the national Institute for Insurance against industrial accidents), in the year 2000 95,000 accidents were recorded in Italy, 250 out of which were fatal accidents.
For companies and the overall community, the economic burden of industrial accidents and diseases is equal to roughly 28 billion euros, 18% out of which regards the building sector.
Focusing on safety while designing buildings calls for an in-depth knowledge of the accident causes and the processes within which it is to be placed.
The reasons for an accident also show the sole attention paid by building companies to the productive aspects to the detriment of a rationalization of the management processes which, conversely, allow to reduce the number of accidents and keep costs under control.
One of the objectives of this paper is demonstrating – by means of a comparative analysis of the total costs and benefits – the economic usefulness of adopting safety management systems, possibly associated with quality management systems.

DATA ON ACCIDENTS IN THE BUILDING SECTOR

The building sector records the greatest number of industrial accidents and diseases of all the productive sectors.

In Europe every year a staggering number of fatal accidents is recorded in this sector (see table I). Indeed, the statistics available at European level (EUROSTAT 1998) show that almost a third of fatal accidents at work involve workers in the building sector.
In Italy the building sector accounts for 10% of the Gross Domestic Product and involves a number of workers equal to roughly 8% of the total manpower.

In Italy, too, the building sector accident trend reflects the European trend. Indeed, according to the 2000 INAIL statistics, every year more than 95,000 serious accidents take place, 250 out of which are fatal ones (see table II).

INAIL statistics show that there are specific and recurrent kinds of accidents which take place in the building sector – a particularly risky sector: the most serious accidents are always caused by falls and the use of means of transport.
The "seriousness" of the damage caused by work in the building sector is also evidenced by the data on industrial accidents (see table III). Indeed, this sector accounts for 16.7% of the diseases being compensated, even though it only accounts for roughly 8% of the total manpower.

Table I. ESAW, accidents at work in the EU by type of activity – 1998

Branches of activity	Accidents at work with more than 3 days' absence from work		Fatal accidents at work	
	Estimated number 1998	Incidence rate %	Number 1998	Incidence rate %
F: Construction	830.873	21,0%	1.330	27,4%
D: Manufacturing	1.354.762	34,3%	1.101	22,7%
G: Wholesale and retail trade	498.926	12,6%	515	10,6%
H: Hotels and restaurant	187.850	4,8%	66	1,4%
A: Agriculture	345.766	8,8%	631	13,0%
I: Trasport and communication	440.143	11,1%	883	18,2%
J+K: Finantial intermediation + renting and business activities	269.727	6,8%	289	6,0%
E: Electtricity+ gas	19.505	0,5%	39	0,8%
Total	**3.947.552**	100,0%	4.854	100,0%

Table II. Recorded accidents at work in the Building sector

Construction – INAIL's data bank					
	1996	1997	1998	1999	2000
Accidents at work- total	98.901	94.113	95.294	98.588	95.131*
Fatal accidents at work	300	304	308	310	251**
Industry and services					
	1996	1997	1998	1999	2000
Accidents at work- total	873.670	845.255	866.495	895.605	904.565*
Fatal accidents at work	1.160	1.235	1.297	1.257	1.148**

** until 31.12. 00*
*** until 31.12.00*

Table III. Construction's sector: professional deseases (incidence rate %)

	Workers	Professional deseases
Construction	8,5	16,7
Industry	41,2	66,4
Industry and services	100	100
INAIL's data bank		

As to industrial diseases, hearing losses and deafness due to noise account for 40% and skin diseases caused by the exposure to substances and products used in working activities account for 24%. Furthermore, over the last few years, many epidemiological studies have shown an increase in the musculoskeletal diseases affecting those working in the building sector.

The industrial accidents and diseases cost about 28 billion euros to the Italian community, 18% out of which regards the building sector.

The cost of accidents is mostly composed of *hidden charges* or, however, of a set of expenditure clements which are logically clearly linked to the accident, but which, practically, are scattered in the meanders of the companies' budgets and are difficult to evaluate.

Therefore, in order to understand to what extent investing in safety is profitable for companies, an analysis shall be made of all the economic components and the losses caused by the existence of the accident risk so as to examine how they can be reduced by adopting a Safety Management System.

THE COSTS OF SAFETY

Besides the direct cost related to the benefits provided by the insurance bodies, the indirect costs and the costs related to prevention shall be also assessed.
Let us examine the various costs that the company has to bear due to the existence of the accident risk, by grouping them under the following classes:

1) *Prevention Costs (PC);*
2) *Insurance Costs;*
3) *Costs for the company as a result of the accident.*

Prevention Costs (PC)

a) expenses linked to the initial phase of the productive activity

- organization of the working place;
- selection of the material to be used (raw materials, semi-finished and finished products);
- selection of the equipment which shall fully comply with the safety requirements imposed by the rules;
- adoption of reliable and safe working procedures;
- expenses for the protection of the environment and of the public;

b) expenses linked to the performance of the working activity:

- overheads for prevention:
  - for the operation of the unit for safety at the workplace: medical service, safety service, staff service, training service and social service;
  - linked to the control on the workers' health conditions, on the protection equipment, on installation and on machinery;
  - for protection equipment (machinery, people);
  - resulting from administrative obligations (book-keeping, files);
- variable expenses for prevention:
  - occasional benefits as a result of the accident: additional training courses, studies, inquiries and inspections;

Insurance Costs

- expenses for insurance against accidents at work:
  - voluntary;
  - compulsory.
- expenses for insurance against the material damage caused by the accident;
- expenses for insurance against dangerous events when this insurance also covers possible accidents at work;

Costs for the company as a result of the accident

a) expenses directly caused by the industrial accident:

- first aid provided directly by the company;
- expenses for the transport of the victim;
- subsidies granted to the injured worker and/or his/her family,
- expenses related to the fulfilment of the administrative and legal procedures;
- wages paid to the injured workers during their sick leave;
- wages paid to other workers during the period of the injured worker's inactivity after the accident and the related procedured to be fulfilled;
- initial performance and results produced by the worker who replaces the injured worker and time needed for his/her training;
- reduction of the efficiency of the disabled worker who, as a result of the accident, performs lower functions;

b) material damage linked to the accident:

- expenses for damage to material, buildings, protection equipment and products;

c) economic losses linked to production losses:

- reduction of production caused by damage to staff or material.

By putting in a Cartesian diagram the Prevention Costs (PC) and the Direct Costs (DC) - stemming from the union of the insurance costs and the costs for the company as a result of the accident - we can obtain the curve of the Cost of the accident (see Figure.1).

Conversely, by analyzing the relation which is established between the two variables, we can observe the progressive reduction of the usefulness of investment in prevention.

Indeed, the trend of the sketched curve depends on the investment "quality"; for example, the dotted curve which is below the continuous one can be related to prevention measures which entail the same financial commitment, but which result more effective and wiser than the previous ones.

The curve can be also used to assess the cost of the prevention measure needed to reduce accidents in the company by a certain amount.

Obviously, for every company the most important goal is reducing the total costs.

Let us examine how the total costs (which are the sum of the prevention costs and the direct costs) vary when the level of safety in the company changes (see Figure 2).

It can be noted to what extent – from the strictly economic viewpoint – it is more profitable for the company to invest in prevention up to the point M where the total costs are at the minimum; beyond that point, also the total costs shall be increased in order to have an increase in the level of safety.

The above stated considerations lead to a situation where a companies choices are made only on the basis of economic criteria.

In practice, for a level of safety to be reached depends not only on the economic aspects of the company, but also on the level of the acceptable total risk that it decides to run; the said level is affected by other variables which, in some cases, play a decisive role.

In this connection – over and above laws, rules and the related pressures exerted by the regulatory authorities - we can also recall the policies implemented by the company, the particular market situations and so on.

In order to increase the level of safety without increasing the total costs, more effective prevention measures shall be adopted which can provide a greater return in terms of safety. This can be done by adopting a safety management system.

Therefore the final result will be a shift downwards of the trough of the curve representing the total costs where the accident incidence is lower.

This is due to the fact that the adoption of safety management systems substantially reduce both the charges linked to the prevention measures and those charges that the company shall bear as a result of the accident.

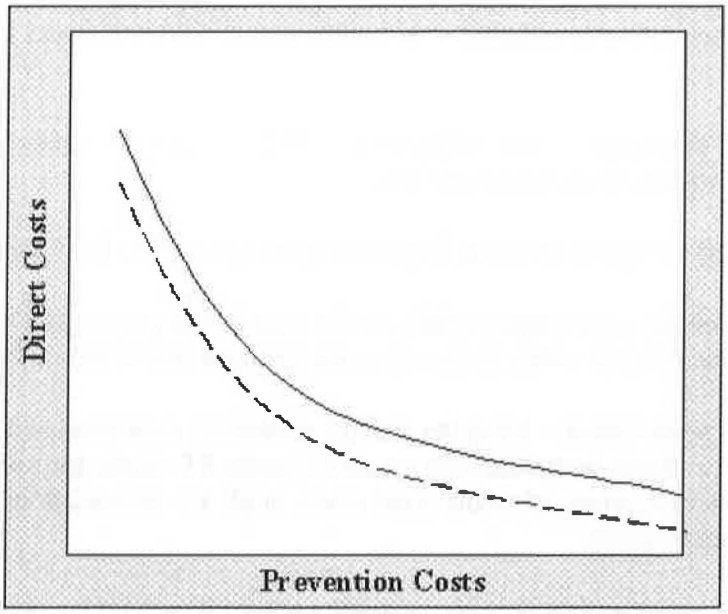


Figure 1. Functional theoretic link between Prevention Costs and Direct Costs

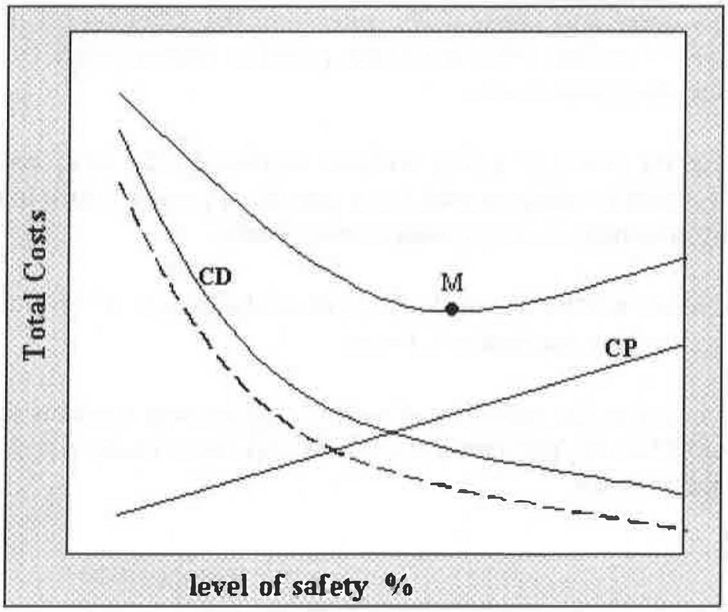


Figure 2. How the total costs vary when the level of safety in the company changes

SAFETY MANAGEMENT SYSTEMS

Recently the transposition of the European Union directives into the Italian legislation and regulatory framework has substantially contributed to encourage companies to invest in prevention both directly and indirectly.

Indeed, the Legislative Decree 626/94 – which transposes the Community directive 89/391/EEC into the Italian legislation – imposes a series of procedures to be fulfilled which no longer allow companies to reduce their investment in safety to the minimum.

It is to be considered that the implementation of the laws on safety at the workplace pushes companies ever more to follow a logical and controlled management of the internal organization, similar to the one which has developed in the field of quality and environmental management. Hence what is done in order to comply with law can become part and parcel of a wider voluntary project to create a safety management system according to a reference standard, namely the OHSAS 18001/99 rules. This system must:

- ensure compliance with the legislation in force;
- define the objectives and a policy for continuous improvements in the field of safety;
- work out reference procedures to check the companies' activity in terms of safety in the workplace and protection of workers' health;
- keep under control the results of the various measures taken in the field of safety.

The legislative approach on safety in the workplace can be placed within a wider context involving management aspects.

Indeed, as is the case with the safety management systems, the rules require a decrease in the number of accidents; a reduction of the residual risk and of the number of workers exposed to that risk; the implementation of the best suited technologies to ensure safety; the maintenance of plants and equipment; the use of the D.P.I.s; workers' training and information, as well as their participation in the companies' planning and management in terms of safety and health protection.

All these elements are included in the tasks of the Prevention and Protection Service to which the legislation refers and can be organized and managed more effectively by resorting to a safety management system.

Indeed, the prevention measure alone (limited to the examination of the working environment) cannot reduce the dangers and risks at the workplace, but must consider the working process as a whole made up of different components:

- man;
- the environment with which he interacts while performing his tasks;
- the procedures and ways which regulate these interactions within a specific environment.

Therefore all the components which play a role within the organization system shall be integrated in one single conceptual framework, by considering the set of rules which are at the basis of the interaction between man and the working process in which he is involved.

In this regard, managing safety does not mean eliminating possible human mistakes considered in isolation with respect to the system, but analyzing and possibly removing from the system itself the conditions which prevent a proper interaction among all the components which contribute to the system implementation and operation.

As regards the safety aspects, the elements needed for the growth and development of a company coincide with the elements which are useful to increase the level of safety itself.

Today the human factor and the social and organization factor are rarely analyzed in the framework of safety at the workplace. When this analysis is made, it is confined to the identification of the human mistake, the effects of which can be perceived immediately and hence easily analyzed. The latent mistakes – namely those associated with the activities far from the place where the accident occurs both in terms of time and space, such as managerial, regulatory and organization activities – are not sufficiently taken into account.

All this happens in a sector where the managerial decisions substantially affect workers' accidents: often companies outsource work to firms which sub-contract them out to others, thus giving rise to situations where different kinds of brokers exist between decision-makers and workers. The use of a management system reduces these problems by identifying those who are in charge of every activity.

The costs that we have analyzed as stemming from the safety procedures to be fulfilled can be reduced or managed in a more productive way if the company decides to equip itself not only with a safety management system, but also with a quality management system.

This is particularly useful, especially for those building companies which work in the sector of public works in Italy.

Indeed, pursuant to the Decree no. 34 of February 25, 2000 implementing article 8 of Law 109/1994 and subsequent amendments, since March 1, 2000 the companies which intend to participate in public works tenders shall have the certification for corporate quality system in line with the UNI EN ISO 9000 rules, or declare to have significant elements of the quality system (closely interwoven one another).

Therefore by adopting an integrated safety-quality management system the company will optimize all the costs resulting from the development and the implementation of any management system. Indeed the costs due to:

- the analysis of the company's internal organization;
- the definition of the organization pattern;
- the training of staff and its involvement to make it aware of the importance to adopt a management system;
- the definition of the working procedures and their standardization;
- the operation of the system at full capacity;

are reduced because the organization has already adopted a management system in-house.

Hence, over and above the possible technical innovations which may be adopted in building companies, the management innovations can introduce those factors which increase the company's competitiveness in a deeply changing market.

The structural change that the building sector is undergoing requires companies to invest in innovations.

Indeed, too often this sector has focused itself solely on the production aspects, thus neglecting the rationalization of the management processes which allow to keep costs under control.

After all it is to be recalled that in the building sector the temporary and mobile nature of the working places hamper the spreading of the safety management systems. Indeed, the management system shall be adjusted to the building yard characteristics on a case by case basis and, while adopting safety management systems, this will entail an increase in costs compared to other standard productive realities such as industry.

Still today the spreading of the safety management systems in the Italian building sector is hampered by the fragmentation of companies, which are mostly small size companies, and for which the adoption of a system has a remarkable economic cost.

Finally we can say that the use of integrated safety-quality management systems can be the prerequisite for a growth reconciling the prevention requirements, the production requirements, the market demand and the innovative and competitive ability that the building companies must be able to provide in order to remain on the market by complying with the laws regulating it.

REFERENCES

[1] INAIL – 1992 – Quanto costano gli infortuni sul lavoro (The costs of accidents at work).

[2] INAIL MONOGRAFIE – 6/1996 – Lavoro e sicurezza nelle costruzioni (Work and safety in the building sector).

[3] G. Ortolani – 3/1990 – L'andamento degli infortuni sul lavoro nell'industria italiana (The trend of accidents at work in the Italian industry) – Rivista infortuni e malattie professionali – INAIL

[4] F. D'Amico, A. Cassanelli, G. Serrecchia, P. Carini – 1983 – Il costo degli infortuni sul lavoro in Italia, aspetti sociali ed economici del problema (The cost of accidents at work in Italy – The social and economic aspects of this problem)– ISPESL.

[5] Flores, L. Freyre – 1997 – La gestione per la qualità in edilizia (Quality management in the building sector) – Il Sole24ore, Pirola.

[6] V. Abrami, R. Tartaglia, S. Palmieri – 1/2001 – La prevenzione degli infortuni ed il miglioramento della qualità del lavoro (The prevention of accidents and the improvement of labour quality) – Il Sole24ore, Pirola.

[7] R. Casilli – 2/2001 – Qualità Ambiente e Sicurezza. La strategia dell'integrazione (Quality, environment and safety. The strategy of integration). – Ambiente e sicurezza sul lavoro.

[8] R. Cadelli - 3/2001 – Il sistema qualità in senso globale. Valore aggiunto per le aziende (The quality system as a whole. The added value for companies) – Ambiente e sicurezza sul lavoro.

[9] EUROSTAT E3/ESAW – 2/2001

[10] C.G. Catanoso – 1995 – Il responsabile del Servizio di Prevenzione e Protezione (The person in charge of the Prevention and Protection Service) – Il Sole24ore, Pirola.

[11] Rinefort – 1977 – A new look at occupational safety. A cost benefit analysis of selected Texas industries – Professional safety. Park Ridge.

ADDITIONAL COSTS IN CONSTRUCTION CONTRACTS FOLLOWING FAILURES IN QUALITY ASSURANCE

Malcolm Murray
School of Construction Economics and Management, University of the Witswatersrand, Johannesburg, (South Africa)
murrayim@icon.co.za

The financial consequences of not following Quality Assurance procedures are often not recognised by contractors' staff. The reasons for failures in compliance with QA procedures are diverse and include: production-quality conflict; poor design and detailing; the employment of untrained workers, particularly on contracts in developing countries; failures in supervision (often of untrained workers); the punch list syndrome and non-recognition of the dire consequences of non-compliance.

The consequences of non-compliance with QA procedures may involve substantial additional indirect costs as well as the direct costs of re-doing work. The application of a simple formula illustrates this contention and a brief description is given of a case study where the need for the reconstruction of a non-critical culvert on a dam contract led to the reconstruction activity entering a critical path. The costs of non-compliance with safety and health assurance procedures can also be high.

Conclusions are that the costs of non-compliance with QA and H & S procedures can be unexpectedly high. Recommendations are that risk assessments of non-compliance should be carried out during the planning stages of a project and communicated to the staff involved.

INTRODUCTION

Quality Assurance procedures are usually established and followed by contractors with the aims of complying with contract specifications, producing good-quality work and satisfying their clients. In the author's experience, however, it is not usual, often for psychological reasons, for contractors to carry out risk – evaluation of the possible consequences of their non-compliance with quality standards.

For similar psychological reasons, contractors tend to advertise, internally and externally, only their successful projects. Projects that went sour quality or cost-wise are usually air-brushed out of the company's portfolio as they are perceived to discredit the company and the staff involved. It is accordingly very rare for "post-mortems" to be carried out of unsuccessful contracts. The reasons for the lack of success are rarely analysed, even if these reasons had been not attributable to the company. Factors which lead to losses on contracts include underestimation of costs and time, poor site management, unforeseen difficulties (which are sometimes claimable) and non-observance of quality requirements leading to the re-doing of work.

This paper examines some of the reasons for failures in quality compliance: these include the use of unskilled professionals (on international contracts, for example) poor supervision, slip-shod control brought about by pressure to meet construction deadlines as well as poor design detailing.

A simple formula is developed which shows that the additional costs incurred by contractors in correcting deficient work can be substantial as indirect, time – related, costs are often involved as well as the direct re-work costs.

A case-study is described of the construction of a dam in Africa where the above issues are illustrated.

Finally, it is felt that the principles described, and the simple formula proposed, could also be used to address the consequences of not following correct safety and health procedures. This theme is not, however, developed in this paper.

The paper concludes with recommendations to contractors (and engineers) on the advantages of carrying out risk-assessment studies on quality-compliance and describes how these could be developed.

QUALITY CONTROL AND QUALITY ASSURANCE

It is believed that Quality Control in the construction industry started to be taken seriously when the first nuclear power reactors were built in the 1960's. The system adopted was to have inspectors monitoring the work of production teams; this inevitably led to conflict between the parties.

Quality Assurance was implemented in the 1970's; the system was developed in Japan and had the merit of making the production teams responsible for their work.

QUALITY ASSURANCE PROCEDURES

The QA system presently in use consists of preparing a Quality Manual prior to start of construction in which procedures are defined and checklists prepared. Section foremen are then empowered to check off the work for which they are directly responsible.

REASONS FOR FAILURE IN QUALITY COMPLIANCE

The Production-Quality Conflict

Production managers and their subordinates are put under constant pressure to complete their section of a contract on, or before, time. The need to comply with quality requirements, which entails the application of a different mind-set to that of the production person, leads to conflict of aims, with quality often suffering.

This conflict is often mitigated when a project consists of assembling pre-cast or pre-assembled units, manufactured under factory condition, as the factory environment with its production-line layout lends itself better to quality assurance procedures.

Poor Design and Detailing

Traditionally, civil construction works are designed by people who sit in offices and have limited construction experience and constructed by construction professionals with little design experience or knowledge. This leads to projects which are often difficult to construct and which are poorly detailed. Increased pressure on consultants to lower costs due to international competition often leads to dropping in quality; this can sometimes be seen in the poor quality of CAD-produced drawings which are often not very illustrative.

Untrained Workers

On the international construction circuit, contractors are often obliged to engage locally-available workers who are frequently untrained and unskilled.

Failures in Supervision

Again, on international contracts, there is sometimes a cultural and communication gap between the expatriate supervisors and the local foremen and artisans.

The Punch-list Syndrome

There is a human tendency to postpone unpleasant, non-productive tasks. This leads to supervisors and foremen putting minor repairs off towards the end of the contract when they can be done all at once. This often leads to the preparation of a huge list of repairs near the end of the contract, at a time when worker motivation is dropping at the prospect of demobilisation and supervisors are starting to focus on their next job. This can lead to time over-runs which evidently lead to cost overruns.

Non-Recognition of the Consequences

Contractors' staff rarely recognise the time and cost consequences of poor construction; it is not a topic which is addressed at universities and technical schools and, as mentioned earlier, contracting disasters, for whatever reason, are rarely post-mortemed and analysed by the people concerned – the staff concerned tend to distance themselves from the unfortunate happening for career reasons.

CONSEQUENCES OF FAILURES OF QA

Direct Costs

The first consequence of poor workmanship is the additional cost of making good the work or re-doing it. As repair costs often turn out to be higher than the original costs, it may be worthwhile to demolish the offending section of work and re-construct it.

What contractors' personnel do not recognise is that making-good work is often drawn-out, tedious and requires a high level of supervision; this in turn diverts supervisors' attention from their normal activities which can lead to a defect spiral and a general disruption of activities.

What is also often not recognised is that defects can lead to an increase of the construction period whether for resourcing reasons (resources are diverted from critical activities to repairs) or because the items being repaired lie on or near the critical path of the project.

Indirect Costs

Increasing the total construction period could lead to disproportional increases in total costs as the on-and-off site indirect costs of the contractor are added on to the direct costs of the repairs.

This happens especially when the contract involves linear construction: of a road, pipeline or even a multi-storey building, where practically all activities lie on the critical path, even if the project has been divided into sections.

Formula

The importance of the indirect cost impinging on direct repair costs can be shown by the use of the following simplified formula:

Assume a contract of value $100

Assuming overhead and profit of	20% + 10% = 30%
Therefore direct costs are	70% x $100 = $70

Assuming the following distribution of direct costs:

labour	30% x $70
materials	40% x $70
equipment	30% x $70

Now, assuming a defect with a direct cost of 10% of the contract direct cost, which leads to an extension of time of 20% of the contract period (which is not unusual) we have:

Additional direct cost	10% x $70 = $ 7

Additional indirect cost	20% x $20 =	$ 4
	Total =	$11

Alternatively, the repairs may involve only labour and materials but, being on the critical path, will cause equipment to be retained on site until the repairs are finished and the equipment can carry on working.

Additional direct cost (labour and materials)	10% x (30% + 40%) x $70 =	$ 4,90
Additional indirect costs:		
Equipment:	20% x 30% x $70 =	$ 4,20
Indirect:	20% x $20 =	$ 4,00
		$13,10

The effect of time related costs is evident: in the first case being 36%, in the second 63% of the total cost.

Put in another way, in the first case, a defect which costs 10% of the contract direct cost would be perceived to cost 7% of the contract sum; in actual fact it could lead to a total cost of 11% of the contract sum. In the second case, a defect perceived to cost 4,9% of the contract sum could actually cost 13,1%.

CASE STUDY

The following illustrates some of the above issues. An earth-fill dam was constructed in Africa in two phases, as shown in Figure 1.

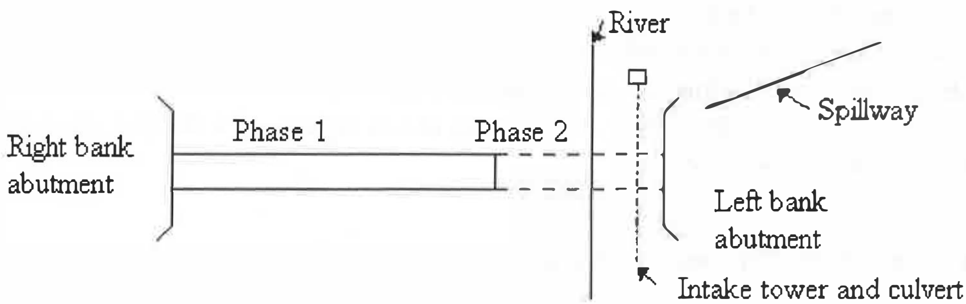


Figure 1. Plan of Dam

Planning of the project envisaged:
Construction of phase 1 while allowing the river to flow through the future phase 2 area
Simultaneous construction in the dry of the intake tower and culvert, following the excavation of the left-hand abutment

The critical path of the works involved constructing phase 1 and then phase 2 during a dry period. A potential critical path lay along the construction of the spillway.

Phase 2 could only be constructed after conclusion of the construction of the culvert, which was initially not on the critical path.

However, due to a failure in quality assurance of the concrete mix used in the concreting of the culvert, a substantial portion of the culvert had to be demolished and re-constructed. Reconstruction could not start immediately as new reinforcement had to be ordered, cut, bent and fixed. This contributed to the delay due to reconstruction being greater than the originally planned period for the construction of the same item of work.

These delays meant that a new critical path came into effect as phase 2 could only be initiated on completion of the repairs of the culvert. The cost of the repair to the culvert consisted therefore of direct and indirect costs.

During the reconstruction of the culvert, this time with a quality-assured concrete mix, difficulties were experienced in concreting: around electrical ducts, under a steel pipe and around expansion joints. These difficulties caused weak areas of concrete to be produced which in turn led to leaking of the culvert following impounding. It is believed that if there had not been so much pressure on the team involved to make up lost time, the design deficiencies would have been addressed and resolved.

Subsequent repairs extended well into the defects liability period and took a total of twelve months to carry out.

Here the following consequences of not following QA procedures can be identified as:

- a serious mistake in concrete mix design
- repair costs being increased by additional indirect costs due to the reconstruction of the culvert establishing a new critical path
- disruption of activities as a knock-on effect
- poor design detailing leading to quality deficiencies
- long-drawn-out difficulties due to the carrying out of repairs of a number of leaking areas subject to external water pressure

SAFETY AND HEALTH ASSURANCE

Techniques similar to those used above can be used to show the knock-on effects on the costs of accidents: work has to be redone and sites are often closed while investigations by insurance and Health and Safety officials are carried out. Where deaths occur, worker morale drops and takes time to be re-established.

A large number of recently reported accidents have involved tower-cranes; the effect on the progress of the works of one of the main items of construction equipment collapsing can be imagined.

On top of the additional direct and indirect costs, there are often substantial damages. Recently in the USA, the families of three workers killed in a crane accident were recently awarded damages of US$ 99,25 million. There were also punitive damages of US$ 94 million handed down against the main contractor – twice the value of the contract. (Trials, 2000).

It was alleged that the crane was employed during a period when wind speeds were higher than recommended.

CONCLUSIONS

The main conclusion is that the actual cost of deficient QA can be much higher than expected. It therefore makes commercial sense for the contractor (and engineer) to avoid deviations from the project specifications.

Similarly the actual cost of non-compliance with health and safety procedures can be very much higher than expected.

RECOMMENDATIONS

It is recommended that:

1) Contractors (and engineers) carry out risk assessment of the consequences of non-compliance with safety criteria during the planning stage of a project.
2) The contractors' staff be briefed on the financial consequences to the contract of non-compliance
3) Contractors' staff be consulted during the design stage of a project to evaluate the constructability of the project.
4) In countries outside the contractor's home base, attention should be paid to training of the labour force and of the supervisors.

Further research could be carried out on

- the real financial consequences of non-compliance with QA procedures
- the real financial consequences of non-compliance with health, and safety, procedures respectively.

REFERENCES

[1] Trials 2000. Verdict turned on wind testimony, *Engineering News Record*, Dec 11, 2000 p. 11-12

ANALYSIS OF ACCIDENT SCENARIO IN CONSTRUCTION DUE TO SAFETY FRAMEWORK

Cristina Reis
Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal

Alfredo Soeiro
Universidade do Porto, Porto, Portugal
Avsoeiro@reit.up.pt

The current study was based on the analysis of the statistics of construction work related accidents in Portugal in the period between 1995 and 2000. Data collected was obtained from several sources including insurance companies, official sources, construction companies, hospitals, police, professional associations, unions and related publications. The final goal was to make a judgement, through comparative analysis of relevant statistics, about the evolution of the rate of accidents in the construction sector in the last six years. One of the objectives of this study was to have some qualitative evaluation of the consequences of the legislative framework implemented in July of 1995.

INTRODUCTION

The issue of safety in construction is currently of particular importance due to the high rates of work related accidents and deaths. With the adoption of the European directive number 92/57/CEE of 24 June through the publication of the Portuguese law 155/95 of 1 of July, the scenario of construction safety has changed. Related with these legal changes there were other initiatives that tried to improve the information and training in this subject. These came most from the government side but there were also efforts made by the unions and contractor associations.

The natural question that arose from this joint effort from several entities addresses the degree of effectiveness of these measures and trying to define the changes needed. There are different benefits from low rates of accidents and one that is considered is the economic study of the accidents in construction. The goal is to analyze the rates of accidents and verify if any beneficial effect took place during the period under surveillance that started after the beginning of the law enforcement until the end of year 2000.

ECONOMIC ADVANTAGES OF EFFICIENT SAFETY IN CONSTRUCTION

The economic analysis of safety in construction attracted the attention of several researchers and some studies were carried out trying to determine the magnitude of the costs associated with the execution and implementation of construction safety plans and the costs of accidents.

The research results used in this paper were obtained from investigations done in collaboration with construction companies, design offices, insurance firms, health institutions, professional bodies, unions, universities and official agencies. These inquiries showed that in economical terms there were clear advantages due to efficient safety systems for all parties involved.

The costs were classified in direct and indirect where direct costs are those identified with the accident in time or place and the indirect costs are all other. The final comparison was made between estimated costs for safety achievement, in the case of having any relevant accidents, and the costs predicted for accidents, occurring due to the lack of safety plans.

The costs of the safety system were evaluated in the phases of design and planning, implementation and control. These values are directly resulting from the costs of the tasks associated and are accounted directly. The costs expected for the possible accidents due to the existence of an insufficient safety framework are estimated based on expected accidents that may be anticipated based on the current indicator of accidents at the national level and only include personal injuries or loss of life. Insurance costs are not affected by the degree of efficiency of the safety scheme and are thus relevant in social terms if accidents occur. The results obtained in terms of average values of the costs of construction accidents are presented in Table I.

Table I. Distribution of Expected Costs of Accidents in Construction

Partners	Share of Costs
Contractor	9 %
Social	18 %
Insurance Company	73 %

The graph indicates that worker insurance is useful for the construction companies since these support most of the costs, that there is a significant portion of the costs being paid by society and contractors are expected to support 8% of the costs. These conclusions are sufficient motivation to explore the decision about the need for possible adaptations of the public policy on construction safety using the data available in the last six years.

CONSTRUCTION ACCIDENT INDEX

To know the types of accidents occurring in the past can help in sustaining an effective prevention strategy. The dedicated statistics are very important to prepare any rational policy on safety and information about the members, types of workers suffering accidents, nature of the injuries and degree of seriousness. The data used is supplied by IDICT (Institute of Development and Supervision of Working Conditions) of Portugal concerning mortal accidents and all others are obtained MESS (Ministry of Employment and Social Security)

There are various indices that address the number of days lost, degree of seriousness, relative importance and level of occurrence. The last was adopted by the World Trade Organization in 1947 in its 6th conference in Montreal and is given by the following expression:

$$IO = A \times 1000 / W$$

where IO – Index of Occurrence, A – Number of work accidents and W – Number of workers. The IO provides the incidence ratio of injuries per 1000 workers during one year.

STATISTICAL ANALYSIS

The analysis of official statistics will abridge the IO concerning fatal and non-fatal accidents in the years between 1995 and 2000. The following table present the official values except for the results of the non fatal accidents in the years between 1998 and 2000.

Table II. Number of Fatal and Non-fatal Accidents in Construction

Year	Workers	Non-fatal	Fatal
1995	120000	43716	112
1996	129000	48641	176
1997	144000	49506	200
1998	150000	---	179
1999	159000	---	152
2000	180000	---	129

While using the index of occurrence, IO, one can verify that there was an increase in the total number of accidents, fatal and non-fatal, between 1995 and 1997 and after this year there was a decrease in the number of fatal accidents. The Occurrence Index however presents a different evolution in these years in the case of fatal and of non-fatal accidents. Non-fatal accidents are those accidents that cause personal harm or prevent the worker to perform but are not lethal.

Table III. Index of Occurrence, IO, for Fatal Accidents in Construction

Year	Workers	Fatal	IO
1995	120000	112	0,93
1996	129000	176	1,36
1997	144000	200	1,39
1998	150000	179	1,19
1999	159000	152	0,96
2000	180000	129	0,72

Table IV. Index of Occurrence, IO, for Non-fatal Accidents in Construction

Year	Workers	Non-fatal	IO
1995	120000	43716	364
1996	129000	48641	377
1997	144000	49506	344

The analysis of the tables show a decrease of the index of occurrence, IO, after 1996 which was almost half a year after the publication of the legal framework for safety in construction. Although not sufficiently substantiated for the non-fatal accidents one can expect a similar reduction to that verified in the fatal accidents.

CONCLUSIONS

It seems clear that the influence of the legislation, the supervision performed, the training and the information campaigns were successful in terms of the index of occurrence for fatal accidents and most probably for the non-fatal accidents. The actual index of occurrence for fatal accidents is almost half of what occurred in 1996 and that shows a firm decline of the accident rates in the construction.

Taking into account that the statistical data only refers to workers with a permanent contract with any construction firm, more data should be recorded concerning temporary workers and illegal workers. It is probable that these workers are more prone to accidents and may increase the global values but the rate of decrease of accidents will probably be similar to these presented.

It is evident that more data related with accidents should be recovered and published concerning accidents in construction. This information should include all workers, regardless of their contractual arrangements, it should contain information about the causes of accidents, and it should be up to date and be as accurate as possible. The coordination of this information should be implemented enabling a database with a rational structure where retrieval of information should be simple and effective.

This type of research should continue to determine the economic consequences of this decrease of the Occurrence Index. The conclusions would allow adjustments on the construction safety policy and would benefit all actors involved.. It will also allow the possible identification of anomalies in the reduction of the accidents in global and relative terms. This identification will probably foster an improved management of the construction safety structure with evident gains for society in general and for contractors in particular.

REFERENCES

[1] Reis C. (1999), Análise Económica da Segurança na Construção – Estudo de Alguns Casos, Master Thesis, FEUP, Porto, Portugal

[2] Reis C. and Soeiro, A (1998), Analysis of Construction Safety Costs, XXV IAHS World Housing Congress, Lisboa, Portugal

[3] Reis C., Soeiro, A. and Santos F. (1999), Economic Overview of Construction Safety, 2nd International Conference, CIB W99/TG36, Honolulu, USA.

[4] Reis C. and Soeiro (2000), A., Factores Económicos da Implementação de Planos de Segurança, International Seminar on Work Safety, FEUP, Porto, Portugal

[5] Statistical Data (1997), Ministério do Emprego e Segurança Social (MESS), Lisboa, Portugal

[6] Statistical Data (2001), Instituto de Desenvolvimento e Inspecção das Condições de Trabalho (IDICT), Lisboa, Portugal

DEGREE OF PARTICIPATION IN SAFETY BY CONSTRUCTION FOREMEN IN HONG KONG

K.W. Wong & H. L. Ho
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong.
bskwwong@polyu.edu.hk

Since the comprehensive review of industrial safety in 1995, the Hong Kong government has made a major shift in formulating safety legislation from a prescriptive approach to a self-regulatory approach, in order to strive for long-term improvement in safety within workplaces. In 1999, the *Factories & Industrial Undertakings (Safety Management) Regulation* was enacted. The construction industry, with its high accident rate at about 200 per thousand workers per annum in 1999, is one of the two industries required under the new legislation to set up safety management system. The foremen, being the front line management on site, play an important role in the safety management system. However, their degrees of participation in safety matters on site are uncertain.

A questionnaire survey is performed on eleven public housing construction sites. The purpose of the survey is to identify the degrees of participation in safety by foremen on construction sites in terms of time spent on the safety matters including: safety inspections, follow-up action after safety inspection, safety meetings, safety training, accidents/incidents investigation, job hazard analysis, enforcing safety rules and keeping safety record. Recommendations for improving the participation of foremen in safety matters on site are included in this paper.

INTRODUCTION

The construction industry in Hong Kong has a poor safety record. The average accident rate per thousand construction workers was constantly over 200 in the last ten years. In 1995, the government had carried out a comprehensive review of industrial safety in Hong Kong and published a consultation paper recommending a change of safety strategy from law enforcement to promoting self-regulation and safety management. In 1999, the government enacted the *Factories & Industrial Undertakings (Safety Management) Regulation.* The regulation provides a legislative framework within which self-regulation is to be achieved through a company based system of safety management. It requires the mandatory development, implementation and maintenance of safety management systems on construction sites and other specified industrial undertakings such as shipyards.

(Mansdorf, 1993) pointed out that top management's commitment with employees' involvement is the essential feature for an effective safety management system. The *Factories*

& Industrial Undertakings (Safety Management) Regulation is drafted in line with this concept. Under the regulation, a safety framework consisting of top management, middle management, front line management, safety personnel and workers should be established for the fulfillment of the workplace's safety policy and objectives. Since front line management provides the crucial link between top management and workers, it forms the essential part within the safety framework.

ROLE OF FRONT LINE MANAGEMENT (FOREMEN)

(Anton, 1989) indicated that the success of a safety programme depends on the sincerity and constant effort of front line management. The front line management is on the job almost all the time and in constant contact with workers. They should exercise safety control since they are thoroughly familiar with the hazards that could develop in the workplace. (Brauer, 1994) expected safety as part of the leadership characteristics of front line management since they directly influence the workers as well as the tasks performed. (Mosley, Megginson & Pietri, 1997) considered that front line management is accountable for safety just as for output or quality. On the other hand, (Hammer, 1989) indicated that front line management has so many duties and schedules to carry out such that they are often overworked. Moreover, (Hale & Glendon, 1987) pointed out that not much is known about the views of front line management on safety responsibility. For the Hong Kong construction industry to implement self-regulation effectively and comply with the new *Factories & Industrial Undertakings (Safety Management) Regulation*, the attitude and degree of participation of front line management in safety matters on site has to be explored.

(Levitt & Samelson, 1993) and (Jimmie, 1997) indicated that by front line management on construction sites it means foremen. In Hong Kong, the Housing Department is currently responsible for providing public housing to over half of the population in the form of rental flats and home ownership units. It has therefore been chosen to represent the local construction industry in this study. A questionnaire survey is arranged to study the time spent by foremen on safety matters on public housing sites. The time spent is used as the means to indicate degree of participation.

QUESTIONNAIRE SURVEY

For the collection of feedback from foremen on public housing sites regarding the time spent on safety matters, a questionnaire survey was conducted. The questionnaire consisted of two parts. The first part was for collecting the background information of the respondent (foreman) including his age, education, job description, working experience and safety training received. The second part touched on the time he spent on safety matters on site including: safety inspections, follow-up action after safety inspection, safety meetings, safety training, accidents/incidents investigation, job hazard analysis, enforcing safety rules and keeping safety record. At the end of the questionnaire, the respondent was required to give an account of total time he spent each week on safety matters and his comments on participation in safety matters.

A total number of eleven public housing sites were randomly selected. The questionnaires were sent to site safety officers for distribution to foremen. A stamped envelope was attached to each questionnaire so that the respondent could individually return the completed questionnaire on voluntary basis. Upon receipt of the completed questionnaires, the data contained therein was recorded and analyzed by the computer software Statistical Package for Social Sciences (SPSS).

Different weighting factor was applied to transform each safety matter into a score for data comparison and analysis. Reference was made to the result of a United States research in 1992 published in *Zero Accident Techniques* by R. W. Liska, D. Goodloe and R. Sen for deciding the weighting factors. The research identified a prioritized list of safety techniques, which, if implemented in a construction site safety programme, would create the greatest impact and result in remarkable improvement in terms of project safety performance. The final list of safety techniques identified by the United States research in the order of importance is shown as follows:

- Pre-job planning for safety
- Safety training
- Safety incentives
- Alcoholic and substance abuse programme
- Accidents and incidents investigation
- Follow-up action and record keeping
- Safety meetings

It was decided that those safety matters that corresponded to higher priorities in the list of Riska's research would be given a higher weighting factor. As a result, the safety matters of job hazard analysis, safety training and accidents/incidents investigation in this survey were given a weighting factor of three. For those safety matters that corresponded to lower priorities, a weighting factor of two was given. As such, safety matters of follow-up action after safety inspection, keeping safety record and safety meetings would have a weighting factor of two. For the rest of the safety matters, no weighting was given.

To obtain the total score of a respondent, the time spent by him on each safety matter was multiplied by the corresponding weighting factor and then added up together. For the sake of simplicity, those time spent below one hour was counted as half an hour during the transformation and score calculation. The score for individual site was the average of the total scores of its respondents. This score was compared with the accident rate of the site to see if there was any correlation. For uniformity, the accident rate was expressed in terms of frequency rate calculated by multiplying the number of lost time accidents by 100,000 and then dividing by the total man-hours.

A total of 127 questionnaires were sent to construction foremen. The number of completed questionnaires eventually received was 76 and at a response rate of 59.8 %. Based on the collected data, 61.8 % of the foremen have received secondary education. Another 23.7 % have studied in technical institutes and 13.2% were trained in the Construction Industry Training Authority (CITA). Also, 63.2 % of the foremen had less than 10 years working experience while another 26.3 % had working experience between 10 to 20 years. Furthermore, 51.3% of the foremen have received the one-day (7 hours) basic safety training known as 'Green Card' training offered by CITA. The remaining 48.7 % received both the Green Card and Safety Supervisor (SS) training. The SS training is a one-week (42 hours) course on basic occupational safety & health theory, specific safety precautions for different work, safety legislation and basic safety management. It aims at preparing the participants to become safety supervisors. About 85.5 % of the foremen were responsible for safety. The remaining 14.5 % were not responsible for safety, which was contrary to the concept of total involvement in safety.

OBSERVATION IN SURVEY RESULT

Overall observation

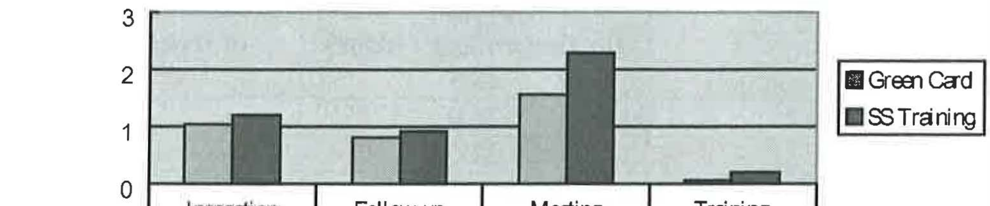
It is noted that the safety matters, of which the foremen had participated more were safety inspections, follow-up action after safety inspection and enforcing safety rules. For the rest of the safety matters, more than half of the foremen did not participate. The average time spent per foreman on each safety matter, which gives a general picture of degree of participation, is calculated and listed in the following Table I.

Table I. Average Time Spent by Foreman on Each of the Safety Matters

Safety Matter	Time Spent (in Descending Order)
Performing Site Inspections	1.1 hour/day
Taking Follow-up Action after Inspection	0.9 hour/day
Enforcing Safety Rules	0.7 hour/day
Performing Job Hazard Analysis (JHA)	0.4 hour/day
Keeping Safety Record	0.2 hour/day
Giving Safety Training to Workers	0.1 hour/day
Investigating Accidents/Incidents	0.3 hour/week
Attending Safety Meetings	1.9 hour/month

Performance of foremen with different safety training

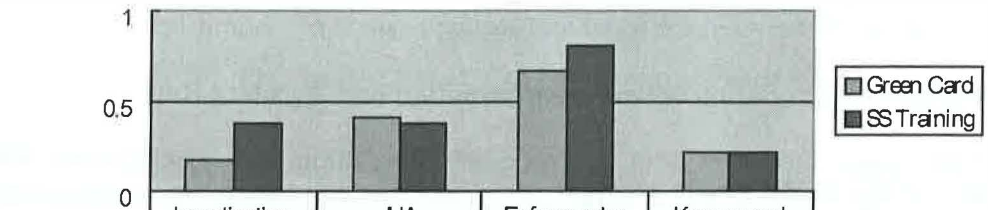
About half of the foremen have received the Green Card safety training while another half have received both the Green Card and SS training. The safety training received by the foremen may affect their degree of participation in safety matters. Therefore, the scores of those foremen receiving Green Card safety training are compared with those receiving both Green Card and SS training by independent samples t-test using SPSS. The result indicated that there is no significant difference between the two group means implying that different safety training does not affect the degree of participation in safety matters. Nevertheless, a comparison was made between the average time spent on each safety matter by foremen with Green Card training and those with both Green Card and SS training. The result is in the following Figure 1 and Figure 2, which showed that a foreman with both Green Card and SS training usually spent slightly more time than his colleague who with just a Green Card.



	Inspection	Follow-up	Meeting	Training
Green Card	1.04	0.81	1.56	0.06
SS Training	1.2	0.92	2.29	0.2

Note : 1) The unit is hour/day except for 'Meeting', which is hour/month
2) SS Training represents foremen with both Green Card & SS training

Figure 1. Difference in Time Spent on Safety Matters – Chart 1



	Investigation	JHA	Enforce rules	Keep record
Green Card	0.17	0.41	0.67	0.22
SS Training	0.38	0.38	0.81	0.22

Note : 1) The unit is hour/day except for 'Investigation', which is hour/week.
2) SS Training represents foremen with both Green Card & SS training

Figure 1. Difference in Time Spent on Safety Matters – Chart 2

Correlation between participation & accident rate

The scores of the foremen in each site were averaged to give the site score. As the accident rate in terms of frequency rate of each site has been obtained, a comparison is made between the two variables. It is assumed that there is a negative correlation between the scores of the sites and the accident rates. The scores of the eleven public housing sites and their corresponding accident rates (in terms of frequency rate) are shown in the following Table II.

Table II. The Score and Accident Rate of Individual Site

Site No.	Participation Score (in Descending Order)	Accident Rate (in terms of frequency rate)
1	25.5	2.6
4	24.0	0.7
5	22.6	0.8
2	16.7	0.6
8	13.8	4.2
7	13.1	3.9
10	12.2	1.3
9	11.8	0.6
6	11.0	1.2
11	8.2	2.5
3	5.8	0.7

To test the existence of such correlation, the simple scatterplot function of SPSS was used. As observed from the scattergram, there is no correlation since the points are scattered around and there is no linear relationship between the score and accident rate. The assumption of a negative correlation between the score and accident rate is not established.

Reasons for No Correlation between Participation and Accident Rate

It has been found that there is in fact no direct correlation between the score, which is an indication of the degree of participation of foremen in safety matters and the accident rate of the site. The non-existence of correlation between the score and accident rate could be due to the following reasons.

Measurement of time spent on safety matters only

The time spent on safety matters is the only selected means to indicate the degree of participation. The other criteria such as attitude towards safety, and allocation of resources are not assessed. Therefore, the result may not be conclusive enough to substantiate the assumed negative correlation.

Foremen participation is just one of the influencing factors

There are other factors influencing the safety condition and accident rate of a construction site. Other significant influencing factors may include top management commitment and safe culture of workers. The degree of participation of foremen in safety matters is just one of the influencing factors.

Even-out effect

It has been revealed that not all foremen were responsible for safety and the participation in safety matters was uneven. This means that some safety matters have very low percentage of participation by foremen. Even if those foremen participating in safety matters performed well and caused enhancement of safety condition in their working areas, the effect could be evened out and become insignificant.

Ownership taken by safety personnel

Safety officers may well have taken the ownership of occupational safety and health. In Hong Kong, safety officer is usually the only person fully accountable for the safety performance and this makes him dominate on site safety matters. In such situation, the role of foremen in safety is less significant and their contribution in the reduction of accidents is limited.

Authority and accountability of foremen is limited

The foremen are at the lower management level on construction site. Their authority is limited and the resources they could utilize are little. This would affect their enhancement of safety condition in their working areas and discourage their enthusiasm in participating in safety matters. This makes the foremen to shift their priorities to work progress and quality instead of safety. They become reactive on participating in safety matters and the safety condition on site may not be improved.

CONCLUSION AND RECOMMENDATIONS

To conclude, construction foremen should play a more significant role as the front line management on site, particularly in respect of safety management. This study comes up with the following recommendations, which aim to improve the degree of participation in safety by foremen.

Promotion of total involvement in safety

To cater for the problem that currently not all foremen are held responsible for safety, the concept of total involvement in safety from top management to workers level should be promoted. This can be achieved by publicizing through mass media and advertisements, dialogue with trade unions and, arrangement of seminars such that all people in the construction industry is aware of the concept. The promotion of total involvement would not just make foremen aware of their responsibility but also cause top management to formulate administrative procedures to make site staff at all levels responsible for safety. Another consideration is by encouraging the agreement of safety charter between proprietor and employees on site. By signing the safety charter, all persons on site acknowledge their safety responsibility. The enforcement of the *Factories & Industrial Undertakings (Safety Management) Regulation* is another way to promote the concept since the legislation requires the setting up of safety organizations within workplaces through total involvement.

Making foremen accountable for safety

Apart from casting the concept of total involvement in the mind of foremen, they must also be held accountable before they would shoulder the responsibility for safety on site. Accountability is a system of role definition, correct measures of performance and adequate reward for safe performance. Accountability forces foremen to take proactive actions. These actions gradually develop a safety culture in working areas. The existence of safety culture may influence workers to improve their behaviour.

Assignment of safety responsibility through negotiation

No foremen would voluntarily accept additional duties assigned to them. To cope with the problem of low percentage of foremen participating in safety matters on site, the finalization and assignment of duty to handle safety matters should be achieved through discussion and negotiation between top management and foremen. This would relief their feeling of being forced to take up the duty. Instead, this will make them understand the need of sharing safety responsibility among people on site. They will shoulder their safety responsibility and participate in safety matters more proactively.

Increase participation by praise & recognition

Encouraging participation rather than punishing non-participation could also alleviate the problem of low percentage of foremen participating in safety matters. Therefore, when foremen start to increase their participation, their effort should be recognized. In fact, one of the most powerful methods of encouraging safe behaviour is to provide social rewards in the form of praise or recognition. This will create a sense of belonging and encourage foremen to strive for better performance.

Specific safety course for foremen

Training organizations such as the Construction Industry Training Authority (CITA) and Occupational Safety & Health Council (OSHC) should consider organizing tailor-made safety training course specifically for foremen. In fact, OSHC has adopted such approach where tailor-made safety training has been organized for local site engineers. In the specific training course, emphasis should be put on the safety responsibility of foremen. The course contents should also aim at equipping the foremen with knowledge and skill for enhancing their performance and participation in safety matters.

REFERENCES

[1] Anton, T. J. (1989) *Occupational Safety and Health Management*, McGraw-Hill, Inc., USA.

[2] Brauer, R. L. (1994) *Safety and Health for Engineers*, Van Nostrand Reinhold, USA.

[3] Education and Manpower Branch (1995) Consultative Paper on The Review of Industrial Safety in Hong Kong, Hong Kong Government.

[4] Hale, A. R. & Glendon, A. I. (1987) *Individual Behaviour in the Control of Danger*, Elsevier Science Publishers B. V., Netherlands.

[5] Hammer, W. (1989) *Occupational Safety Management and Engineering*, 4th Edition, Prentice-Hall, Inc., USA.

[6] Jimmie, H. W. (1997) *Construction Safety*, Prentice-Hall, USA.

[7] Liska, R. W., Goodloe, D. & Sen, R. (1993) *Zero Accident Techniques*, Construction Industry Institute, USA.

[8] Levitt, R. E. & Samelson, N. M. (1993) *Construction Safety Management*, 2nd Edition, John Wiley & Sons, Inc., USA.

[9] Mansdorf, S. Z. (1993) *Complete Manual of Industrial Safety*, Prentice-Hall, Inc., USA.

[10] Mosley, D. C., Megginson, L. C. & Pietri, P. H. (1997) *Supervisory Management*, 4th Edition, South-Western College Publishing, Cincinnati, Ohio, USA.

PROCEEDINGS

COSTS AND BENEFITS RELATED TO QUALITY AND SAFETY AND HEALTH IN CONSTRUCTION

TUESDAY, 23 OCTOBER 2001

TOPIC: METHODS TO MEASURE QUALITY AND SAFETY AND HEALTH PERFORMANCE IMPROVEMENT.

AUDITING AND MONITORING HEALTH AND SAFETY IN METRO DO PORTO

José M. Cardoso Teixeira
Universidade do Minho, Campus de Azurém, 4800 Guimarães, Portugal, *jct@eng.uminho.pt*

L. Miguel Azevedo
Normetro, Rua Actor Ferreira da Silva 100, 4200-298 Porto, Portugal,
miguel.azevedo@normetro.pt

Integrated Management Systems for Health & Safety, Quality and Environment in construction projects is often a desirable objective for most contracting organisations. In most cases, the Quality Management System is developed before the Health and Safety and the Environment Management Systems have been decided. Therefore, the latter are created under an alignment approach to the former, aiming at their progressive integration. However, health and safety auditing faces specific problems related to the nature of human behaviour interpreting and evaluating risk. This paper is about auditing and monitoring the Safety Management System of Metro do Porto at the contractor organisation. Health and safety control starts at the design phase involving designers and recording their decisions and suggestions. During the construction phase, site inspections are often performed. However it has been found that site inspections do not efficiently assess unsafe acts by workers. In addition to site inspections two types of audits are conducted: external audits performed by the client, covering the design, tender and construction phases of the project and internal audits undertaken by the contractor organisation in order to determine the effectiveness and the efficiency of the Health and Safety Management System previously developed. The latter implies not only checking procedures and paper work but also the actual commitment of the consortium staff in health and safety matters. A case study from the authors experience is presented evidencing internal auditing procedures..

Keywords: Construction design, Safety, Safety Management Systems.

INTRODUCTION

Normetro is a seven-company consortium constituted for the design, construction, installation and operation of Metro do Porto. The project has been successfully awarded in 1998. According to the contract with the client, Normetro should develop and implement a Safety Management System (SMS) aiming at:

- Ensuring common health and safety management procedures among all partners;

- Assuring the client that Normetro consortium will comply with health and safety requirements from the preliminary design phase to project commissioning.

According to the contract, this SMS should focus on occupational health and safety of workers involved not only in construction and installation of the system, and workers assigned to operate it. System safety ensuring that the project is safe for its intended use, is developed under a different management system.

NORMETRO SAFETY MANAGEMENT SYSTEM

When the development of the SMS was decided, Normetro had already been developing a Quality Management System QMS), within the frame of ISO 9000 standards, and good receptiveness of partners had been reported. Therefore, it appeared that the SMS would preferably be implemented following earlier positive quality experience, and an alignment between the two systems was decided. The following advantages of this option have been foreseen:

- The QMS was developed in the framework of the ISO 9000 series that could be used as a template for the SMS;

- The QMS had been successive in getting Normetro's management commitment, contribution from all partners for further improvement, support from the project management team and approval from the client;

- People in the organisation appeared to be motivated and sensitive to the implementation of the QMS;

- The development of a new different management system for safety could create some confusion to workers and introduce avoidable complexity in the organisation.

Furthermore, the alignment of these two systems allows for their progressive integration. The integration of different Management Systems is a topic of great concern in the literature. Total Project Management (TPM) embodies the ideals of full integration of system like these and this was also the philosophy adopted by Normetro in its organisational chart. Specifically, the integration of quality, health and safety and environmental management systems has deserved substantial reflection.

Normetro produced three different management systems within ISO 9000 standards, covering quality, health and safety and the environment. Despite Normetro's intention of future integration among those management functions, a separated although aligned approach has been followed.

Correspondence between OHSAS 18001 and Normetro SMS

Table bellow shows the correspondence between OHSAS 18001 requirements and documents of Normetro Safety Management System, or points those fulfilled by the Quality Management System (QMS).

Clause	Requirements	NORMETRO Safety Management System	Obs.
4	OH&S management system elements		
4.1	General requirements		
4.2	OH&S policy	Safety Manual	
4.3	Planning		
4.3.1	Planning for hazard identification, risk assessment and risk control	Design Control Procedure Inspection, Prevention and Control Procedure	
4.3.2	Legal and other requirements	Safety Manual	
4.3.3	Objectives	Safety Manual	
4.3.4	OH&S management program	Safety Manual	
4.4	Implementation and operation		
4.4.1	Structure and responsibility	Safety Manual	
4.4.2	Training, awareness and competence	Information and Training Procedure	
4.4.3	Consultation and communication	Safety Manual	
4.4.4	Documentation		QMS Procedure
4.4.5	Document and data control		QMS Procedure
4.4.6	Operational control	Inspection, Prevention and Control Procedure	
4.4.7	Emergency preparedness and response	Accident Management Procedure Health and Safety plan Procedure	
4.5	Checking and corrective action	Inspection, Prevention and Control Procedure Stop and Restart of Works Procedure	
4.5.1	Performance measurement and monitoring	Inspection, Prevention and Control Procedure Safety Statistics Procedure	
4.5.2	Accidents, incidents, non-conformances and corrective and preventive action	Accident Management Procedure Non Conformity Control Procedure Stop and Restart of Works Procedure	
4.5.3	Records and records managements	Safety Record Control	QMS Procedure
4.5.4	Audit		QMS Procedure
4.6	Management review	Safety Manual	QMS Procedure

CONTROLLING HEALTH AND SAFETY

Design phase

According to the principles of the EC Directive 92/57/CEE, designers ought to consider health and safety in their design options. Because a large number of design teams have been contracted and they perform their work in a variety of distant locations, a control methodology of their involvement was required. Basically, designers must conduct preliminary hazard identification for work activities covered by their work. Thereafter, they are required to reflect upon design options to eliminate or limit hazards to an acceptable level and to suggest safety measures to implement on site, in order to prevent residual risks for workers involved. These activities of the design teams are summarised on the "Design Control Record" form [1]. This is an essential control document for design safety co-ordination because it allows for monitoring the work performed by the design team and enables action to be taken if solutions for risk prevention are not satisfactory. Therefore this document is suitable for some looping before reasonable solution can be met. Eventually, the results of this process are used as valuable inputs for health and safety plans produced during the design phase.

Construction phase

As required by the law, a Health and Safety Plan is produced for each site, which is also used as a basic health and safety control document for construction activities encompassing the following control components:

Safety inspection procedures. These are the basics for monitoring the most relevant construction tasks and are intended to cover the most significant risks. They also state how often should an inspection be done and records produced. Besides, they are also used as control documents for safety problems, which are dealt with according to their severity:

- Low severity safety problems. The safety inspector alerts the site manager, suggests corrective measures that are immediately implemented. No record is produced.
- Severe safety problems. A "non compliance record" is produced and corrective measures should be suggested by the site manager and approved by the Construction Safety Co-ordinator.
- High severity safety problems. If the problem is very serious, cannot be immediately corrected and might endanger public or worker safety, the work is halted, till proper measures are implemented

It is thus essential that site inspections may encompass follow up activities and may identify staff responsible for corrective actions. However this procedure has a serious drawback because, in order to be effective, it requires a large number of inspectors with proper training. Besides, the results of inspections may not adequately reflect the safety attitude of workers, but just their performance on a specific time instance. A more effective approach is motivation of Site Management and foreman for health and safety issues [6].

Accident reports and accident statistics. All site accidents, with injuries, must be reported. A copy of each accident report is sent to the client, and, depending on the severity of the injury, an investigation is conducted. The investigation can be ordered by the Safety Manager or by the General Manager. Accident statistics are built up from accident reports and include incidence and frequency rates. Although accident statistics are a measure of safety performance, they cannot be used as a control tool because they only provide retrospective analysis. Moreover they do not provide indication of the weakness of the SMS, just of the direct cause of accidents.

Subcontractor document control. Prior to starting their works, subcontractors must deliver some documents, as required by the Health and Safety Plans. Subcontractors are not allowed to start any work if all due documents have not been received, checked and approved by site safety staff. These are also used as control documents.

Monthly Safety Reports. In order to organise all this information, a monthly safety report is produced and copies of it are sent to the client, and its representatives, as well to the managers of all Normetro's partners. The report is a balance of all safety activities, covering:

- Major developments on work activities;
- Most relevant unsafe situations reported;
- Non conformity records issued (internal and external) and corrective measures;
- Safety statistics;
- Safety activities planed for the next month.

Client site inspections.

Site inspectors working on the client behalf perform unscheduled safety inspections. Safety problems possibly detected are categorised under the following headings:

- Unsafe situations. Normetro is notified, but a "non conformity" record is not issued.
- Non conformity record. As the internal non-conformity, corrective measures have to be proposed by the site manager, but approval has to be conceded by the client safety inspector.
- Stop work order. Issued for very serious safety situations.

Client inspections have similar drawbacks as those performed by the contractor. Alternatively, joint inspections of the two parties could possibly be advantageously implemented because they enlist their common involvement in the site safety. Additionally, this approach provides the opportunity for individuals to better understand the challenges and expectations faced by each other in regard to integrating safety into daily work practices [2].

AUDITING

Internal Audits

Safety control activities performed by Normetro are an important part of the safety system, but are not enough to assess and evaluate the effectiveness of the system. They may possibly reveal if safety conditions on site are satisfactory but do not allow assessing if that is done in an organised and systematic way. This is achieved by conducting internal audits in the organisation.

Following the aligned approach mentioned above, safety audits are performed under the frame of the audit procedure of the Quality Management System. This procedure allows for two kinds of audits:

- To check and evaluate if and how system procedures and manuals are in accordance with legal or contractual documents.
- To assess if the system is effective, that is, if procedures are known, accomplished, useful and adequate for the organisation activities.

The audit plan was designed and conducted in order to cover mainly the second aspect of the audit procedure. The following main aspects of safety management in the organisation are treated:

- Management;
- Planning;
- Consult;
- Risk management and control;
- Training.

Audit checklists where produced in order to help and assist the auditing process. However, when producing them an effort was made not to produce a procedure-based checklist, but one with a wider approach [3].

Case Study

The following example shows a checklist produced for an internal auditing process recently conducted in the consortium. Although with a different approach and item organisation it covers most OHSAS 18001 and Normetro SMS clauses [4]:

Management

1.1	The employer responsibilities are identified
1.2	The employer responsibilities are understood
1.3	The employer is involved in safety management
1.4	Health and safety activities are co-ordinated.
1.5	There is an health and safety policy
1.6	The health and safety policy is understood
1.7	Adequate resources are available
1.8	Safety management activities are achieved on schedule

Planning

2.1	Safety management is planed
2.2	There are objectives
2.3	Achievement is evaluated
2.4	Specialists are used
2.5	Safety management is regularly evaluated
2.6	Recommendations are followed
2.7	Information is available
2.8	Suppliers are selected based, also, on safety requirements
2.9	Suppliers work in order to fulfil safety requirements
2.10	There are concerns with visitors safety
2.11	There are concerns with workers with special needs
2.12	There are emergency procedures

Consult

3.1	Consult needs are identified and understood
3.4	Consult is made considering health and safety issues

Inspection and control

4.1 Accidents are reported
4.2 Accidents are investigated
4.3 Sites are inspected
4.4 Hazards are identified
4.5 Risks are evaluated
4.6 Work activities are analysed
4.7 Risk control is planed
4.8 Risk control is implemented
4.9 Risk control is evaluated and corrected
4.10 New dangers are managed

Training

5.1 Training requirements are identified and understood
5.3 Training needs are analysed
5.4 Training is planed
5.5 Training has clear objectives
5.6 Training is provided
5.7 Training is evaluated
5.8 Workers can follow emergency procedures.

People to interview were selected so that the organisation would be adequately covered. A special attention was directed towards the construction companies of the consortium.
Selected people where distributed into five different groups, according to their role:

- General management;
- Safety management;
- Technical, production and contractual management;
- Site safety personnel (safety technicians and construction safety co-ordinator);
- Site personnel (management and operational).

During the audit, separate interviews were conducted. Basically the audit checklist was the same for all the interviews, although some adjustments have been made, cutting and adapting some items, if not relevant for a specific interview. Furthermore, a special care was taken, while conducting the interviews, in order to take into account behavioural aspects towards safety and Normetro SMS, especially from those not directly involved in safety management [5, 6].

The approach followed in each interview was also different, using the checklist as an assistant to the interviews, in an open and easily adaptable way, and not as a closed and blinded guide. For example, when interviewing the general manager about the safety policy items, typical questions were:

> "*Is there an health and safety policy*?"; "*what are the basis of that policy*?"; "*Do you think the policy is understood*?"; "*How do you publicise the health and safety policy*?".

When interviewing site workers about the same items, a different kind of questions were formulated:

"Have you heard about the health and safety policy?"; *"Are you aware of the health and safety policy statement?"*

External Audits

External safety audits performed by the client representatives mainly focus on current procedures and comparing to contractual documents. These audits are directed to the most important management functions in the organisation:

- Safety Manager
- Design Safety Co-ordination
- Construction Safety Co-ordination

For each one of the functions above the audit process is based on checklists administered to selected auditees.

CONCLUSIONS

Health and safety control in Metro do Porto project starts at the design phase and aims at the participation of Design Safety Co-ordination and Design Professionals in the search for adequate solutions for risk prevention on site. This methodology goes beyond traditional control activities as it brings together all main participants concerned. Moreover, this is in agreement with the EC Directive 92/57/CEE, which encompasses a similar approach for the design phase.

The Health and Safety Plan produced for the construction phase contains essential site control documents. Its main control components for that purpose rely on safety inspections but these may not adequately reflect workers attitude towards health and safety. Furthermore, too heavy monitoring effort implies too many resources allocated to it and this is frequently incompatible with project economics. Support from management and workers motivation may possibly compensate lower inspection effort.

Internal safety control activities have been, so far, quite efficient. Incident and frequency rates in Normetro construction sites are well bellow the average of Portuguese construction industry (see table bellow). Non conformity records are not current. Site safety personnel tend to solve unsafe situations directly on site, in co-operation with the site manager.

Internal audits to the Safety Management System have been based on checklists aiming at assessing the effectiveness of the system. Some organisational and management problems have been evidenced by internal audits so far. Client audits have been more directed to documents rather than practices, detected some failures, especially in recording and controlling records of safety management activities.

	Incidence rate	Frequency rate
NORMETRO, ACE	33.0	13.8
Portuguese Construction Industry (estimate)	122.7	56.3

ACKNOWLEDGEMENTS

SMGP Consultores, Lda.
Normetro ACE
CGK
Metro do Porto, SA

REFERENCES

[1] TEIXEIRA, José M. Cardoso; AZEVEDO, Miguel (2000); Design safety co-ordination in Metro do Porto. Designing for safety and health Proceedings, ECI, London, June, 2000.

[2] HISLOP, Richard D. (1999). Construction Safety. A guide for managing contracts. Lewis Publishers

[3] KASE, Donald W; WESE, Kay J. Safety Auditing. A Management Tool. Van Nostrand Reinhold.

[4] WorkSafe Plan. Western Australia's Assessment of Occupational Health and Safety Management Systems, January, 1999.

[5] VAN GOOLEN J.; OP DEN CAMP L. CRUMFINGER A. Behaviour Based Improvement of Safety and Health During the Construction Phase. Designing for safety and health Proceedings, ECI, London, June, 2000.

[6] COBLE R. J.; HAUPT T.C. Potential Contribution of Construction Foreman in designing for Safety. Designing for safety and health Proceedings, ECI, London, June 2000

A CASE FOR THE IMPLEMENTATION OF QUALITY MANAGEMENT IN ROOF CONSTRUCTION

John Christian, L. Newton, T. Gamblin
University of New Brunswick, Fredericton, (Canada)
jchristian@unb.ca

Roofing inspections were made on flat and low-slope roofs on the University of New Brunswick=s Fredericton campus. The data from these roof inspections was entered into a computerized maintenance management system called MicroROOFER and a roof condition index (RCI) was calculated for each roof section. An RCI is a rating from 0 - 100 of the roof=s condition where A0" is a failure condition and A100" is an excellent roof condition.

It was found that for roofs greater than 20 years of age, the RCI decreased with age. However, roofs less than 10 years of age, showed a decrease in the RCI with newer roofs. This trend was the opposite of what was expected. It was determined that the lower RCI could be due to several factors: the lack of quality management in design and construction; a lack of a roof maintenance management system; a lack of funding for maintenance expenditures; or a combination of one or more of these factors.

This paper presents the results of the research and makes a case for the need to implement a comprehensive quality management program that can be applied to the design, construction and maintenance of roofs.

INTRODUCTION

Roofs are a critical component of the building envelope. Many factors can lead to the early deterioration and failure of roofing systems if care, inspection, and maintenance are not carried out throughout the service life of the roof. These factors include environmental degradation factors (high and low temperatures, solar radiation, water, wind), traffic loading, inadequate maintenance, and poor workmanship. Consequently, if inspections are not made and care is not taken, unforeseen, expensive repair or replacement costs arise. To extend the life of roofing systems and to reduce unforeseen costs, a comprehensive quality management program which can be applied to the design, construction and maintenance of roofs is necessary.

BACKGROUND

During the summer of 2000, visual inspections were undertaken on the flat and low-slope roofs of the University of New Brunswick=s (UNB) Fredericton campus as part of a collaborative research project with the Institute for Research in Construction (IRC). The inspection procedure used was developed by the United States Army Construction Engineering Research Laboratory (USACERL) and the IRC as part of the Building Envelope Life Cycle Asset Management (BELCAM) project. The BELCAM project is attempting to address growing problems faced by Canadian asset and building managers regarding when and how to repair or replace their building stock and components (Vanier and Lacasse, 1996).

A series of inspection and distress manuals (Shahin et al., 1987, Bailey et al., 1990, Bailey et al., 1993) were developed by the USACERL and modified by IRC (Lounis et al., 1998) to standardize roof inspection procedures for the BELCAM project. Flat and low-slope roof inspection procedures for built-up roofs (BUR), modified bitumen roofs, and single-ply membrane (SPM) roofs are outlined and distresses are identified for both the flashings and the membrane in these inspection and distress manuals. Names, descriptions, severity levels, and photographs of specific defects along with measurement criteria are presented for each distress in the manuals.

Data from the visual inspections were recorded on roof inspection worksheets and then entered into a computerized maintenance management system (CMMS) called MicroROOFER (USACERL, 1995). MicroROOFER is used to maintain a roof inventory database, to provide a roof repair history and to calculate roof condition indices (RCI). Condition indices are used to establish the technical condition of an asset, in this case, a roof. The RCI can be broken down into an index for each of the three main roof components namely, a membrane condition index (MCI), a flashing condition index (FCI), and an insulation condition index (ICI). Each individual index reflects the component=s ability to provide its intended service.
The roof condition index is calculated by MicroROOFER using the following formula:

RCI = {0.7 H min (MCI, FCI, ICI)} + {0.15 H [(MCI + FCI + ICI) - [min (MCI, FCI, ICI)]]}

This equation gives the greatest weight to the component with the lowest condition index and then modifies it by adding Avalue@ from the remaining indices (Bailey et al., 1990). The roof condition index is a number from 0 - 100 where A0" indicates a failed roof and A100" represents a roof with no distresses or defects. MicroROOFER calculates the individual indices based upon the type, quantity, and severity of the defects found in the roof inspection. The ICI is based on nondestructive moisture tests or internal methods of inspection, such as Infrared Thermography (IF). Infrared Thermography was not undertaken in this research. The findings presented in this paper are restricted to roof condition indices based on only flashing condition indices and membrane condition indices (i.e. external or visual inspections).

RESULTS

The condition or performance of roofing components and systems deteriorate with time as a result of environmental degradation factors (temperature, solar radiation, water, wind), traffic loading, inadequate maintenance, and poor workmanship (Lounis et al., 1999). Typically, an older roof should be in worse condition or have a lower roof condition index (RCI) than a newer roof. This was not the case however, with the newer roofs on the University of New Brunswick=s Fredericton campus. As shown in Table I, the RCI decreased as the age of the roof increased for roofs greater than 20 years of age. This trend is expected if all things (i.e.

environmental degradation, traffic loading, maintenance levels, and quality of workmanship) are relatively equal. For roofs less than 10 years of age, however, there was a decrease in RCI for newer roofs. This is obviously the opposite of what is expected. This trend is shown graphically in Figure 1.

Table I: RCI as a function of the age of the roof

Year of Last Construction	Age Range of Roof Section (years)	Number of Sections	Total Area (ft^2)	Total Area (m^2)	Average RCI
# 1960	40 +	27	49 939	4639	56
1961 – 1965	35 - 39	23	49 499	4599	61
1966 – 1970	30 - 34	25	68 989	6409	69
1971 - 1975	25 - 29	23	89 629	8327	77
1976 - 1980	20 - 24	0	-	-	-
1981 - 1985	15 - 19	8	20 854	1937	88
1986 - 1990	10 - 14	7	30 865	2867	88
1991 - 1995	5 - 9	13	70 930	6589	76
1996 - 2000	0 - 4	23	39 411	3661	74

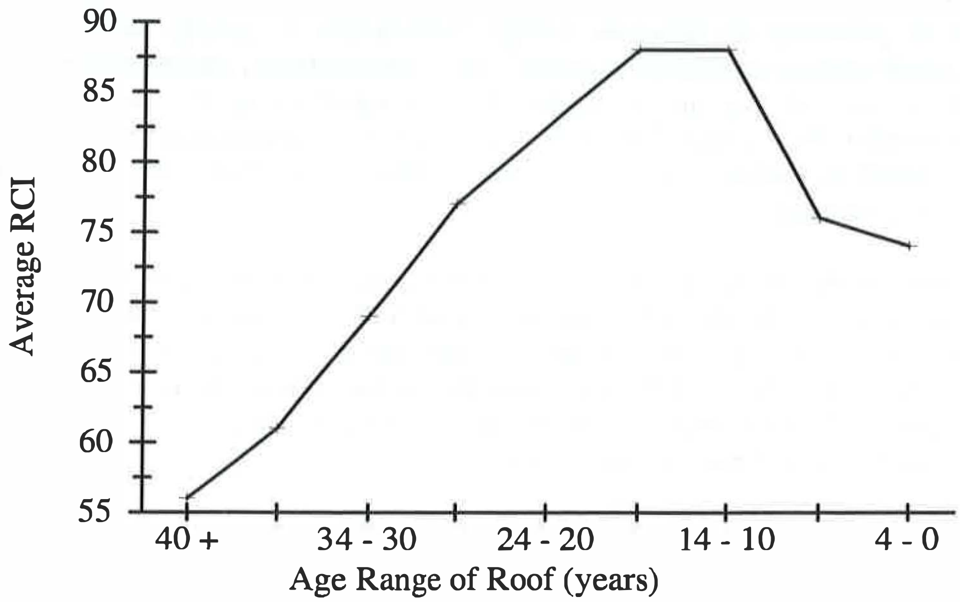


Figure1: Average RCI vs. age of roof

DISCUSSION

As previously mentioned, the condition or performance of roofing components and systems normally deteriorate with time as a result of environmental degradation factors (high and low temperatures, solar radiation, water, wind), traffic loading, inadequate maintenance, and poor workmanship. Why then, is the RCI for newer roofs less than that of some older roofs in the 1981-2000 range? Environmental degradation factors can be considered a constant for the roofs at the University of New Brunswick=s (UNB) Fredericton campus because they are in the same location. Since none of the roofs are used as patios, the traffic loading is relatively the same and minimal for all roofs on campus. This leaves the quality of workmanship, quality management in design and construction, or the maintenance management systems as the potential cause of the lower RCIs.

QM in Design, Construction, and Workmanship

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 installed, flaws and inconsistencies in the roof design and details will result in poor performance. This leads to roof leakage, reduced energy efficiency, and possible structural failure.

For roof replacement projects at the University of New Brunswick=s Fredericton campus, design and construction is typically contracted out locally. This allows the design and construction contractors significant latitude in what they provide and how they provide it (materials and methods) (Bailey and Adiguzel, 1999). The University, therefore, has limited assurance that they are receiving an adequately designed roofing system for the specific building. 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. Further quality could be assured if the architect, engineer, or design company were also members of groups such as the CRCA (Canadian Roofing Contractors= Association), IRWC (Institute of Roofing and Waterproofing Consultants International), or the RCI (Roof Consultants Institute). This would then ensure that the design contractor has the capabilities of providing an adequate design. 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. In addition, membership in the CRCA should also be a prerequisite for the contractor.

Another factor that affects the performance of a roof is the type of materials used in the roof membrane construction. It is not sufficient to assume a 20 year service life for a roof. Schneider and Keenan (1997) calculated the average roof life from a database of over 24 000 roof systems. As shown in Table II, different membrane materials yield different service lives. Thus, if a built-up roof (BUR) is constructed under the assumption that it will be in service for at least 20 years, problems will most certainly arise.

From an examination of the UNB roof inventory data (see Table III) the lower RCIs could not be attributed to one type of membrane material. Thus it could not be said that the lower RCI, for roofs less than 10 years of age, were a result of the membrane material used in construction.

Table II: Average service life of roofing system by membrane type (Adapted from Schneider and Keenan, 1997)

Membrane Type	Average Service Life (years)
Asphalt BUR	14
Coal Tar BUR	18
Modified Bitumen	17
SPM	18

Table III: Membrane material used in the construction of roofs at UNB

Year of Last Construction	BUR		Modified Bitumen	SPM
	Asphalt	Coal Tar		
# 1960	-	27	-	-
1961 - 1965	2	21	-	-
1966 - 1970	23	-	2	-
1971 - 1975	-	23	-	-
1976 - 1980	-	-	-	-
1981 - 1985	2	-	-	6
1986 - 1990	-	-	-	7
1991 - 1995	6	1	6	-
1996 - 2000	7	9	4	-

To make sure that proper materials and methods are being used, 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. Hiring a third-party QC inspector will add approximately 2 to 4 % to the roofing costs (Bailey and Adiguzel, 1999) but the benefits are easily realized.

It is difficult to evaluate from past records if appropriate construction methods were used on UNB roofs. This is pertinent because there was no QC inspector present on the site at the

time of the roof construction. For this reason, it is unknown if the methods used in the construction of UNB roofs is a detrimental factor for roofs less than 10 years of age.
Maintenance Management Systems

Implementation of a roof maintenance management system (RMMS) as suggested by Froese, Hassanain, and Vanier (1999) consists of five steps:

1) Identification of roofing system components requiring assessment,
2) Identification of roofing system performance requirements,
3) Identification of performance assessment methods,
4) Roofing system maintenance planning, and
5) Roofing system maintenance operations management.

Identification of roofing system components requires the acquisition of information such as the top cover type (if any), membrane type (BUR, modified bitumen, or SPM), insulation type (and thickness), vapour/air barrier type (if any), roof deck type (steel, concrete, etc.), and flashing types (s). Other information that is useful when identifying the roof components includes, but is not limited to, the year of roof construction (original and/or replacement), building identification (unique identification number, building use, etc.), repair history, roof warranties, manufacturer information, and roof drawings. This data can then be used to form a detailed roof inventory.

After identifying the roof system components, it is necessary to identify the purpose of the roof system components. That is, how does each component contribute to the overall performance requirements of the roof (water tightness, energy efficiency, and structural support)?

Performance assessment methods are ways in which the performance requirements of roofing components are evaluated. This is done by scheduled roofing inspections using two techniques, external (visual) and internal (empirical testing) inspections. External inspection of roof components is done visually from the top of the roof, while internal inspection can be done using destructive and/or nondestructive testing. Internal inspections can be done by: Destructive Moisture Tests, including Roof Cut Tests and Moisture Meter Tests; and Nondestructive Moisture Tests, including Infrared Thermography (IF), Nuclear Moisture Detection and Capacitance Radio Frequency Scanning (CRF) (Froese, Hassanain, Vanier, 1999).

Maintenance, repair, and replacement planning can be undertaken more effectively if the current condition of roofing assets are known. If the condition is not known and leaks occur, immediate remedial work is both disruptive and an inefficient use of resources. Projects can be prioritized and roofing budgets can be more optimally allocated when properly programmed. Tools such as MicroROOFER, which has a maintenance, repair, and replacement function can be used to aid in these decisions. US Army installations, which have implemented the use of MicroROOFER and routinely use it, have been able to increase the benefit from their roofing maintenance and repair costs (Bailey and Adiguzel, 1999).

The University of New Brunswick does not currently utilize a roof maintenance management system (RMMS). By implementing an RMMS, performance of roofing systems can be monitored. If early failure occurs, which may be occurring with roofs at UNB less than 10 years of age, manufacturer=s warranties may still exist which could result in significant savings for remedial work.

Maintenance Funding

In optimal conditions, the annual budget for maintenance and repairs of a roof should be between 2 and 4 % of the cost of a roof replacement. This is quite often not the case, however. When budget cuts are made, general maintenance is usually the first place where money is withheld. This is because the end result of deferred maintenance is not imediately seen by facility managers or owners. A crisis management approach is adopted instead. It is easier to justify spending money for a visible problem than it is to justify spending money to prevent problems from occurring in the first place. It is not until a roof leaks at the most inopportune time that the costly effect of deferred maintenance becomes a reality and extra costs are spent to fix something that could have been avoided at a much lower cost.

Unfortunately, the maintenance expenditures for the roofs at the University of New Brunswick=s Fredericton campus were not available. It is speculated that if there has been a decline in available funds for maintenance expenditures over the past 10 years at UNB, that this would be the reason for the lower RCI for newer roofs.

FUTURE RESEARCH

Visual inspections of the roofs at the University of New Brunswick=s Fredericton campus will be undertaken again in the summer of 2001. This data will be entered into MicroROOFER and an RCI will be calculated for each roof and compared against the benchmark established in 2000. The effect that the lack of a quality management program has on the declining condition of roof infrastructure will be studied in more detail including the amount of funding allocated for maintenance expenditures.

During the summer of 2001, visual inspections will also be undertaken on the roofs at the Combat Training Centre (CTC) Gagetown in Oromocto, New Brunswick. The Department of National Defence (DND) has had great success with their roofing systems. The actual service life of some roofs is twice as much as the design service life, extending to over 40 years. DND=s extensive quality management program will be investigated and compared with that of UNB in an attempt to prove the benefits of implementing a comprehensive quality management program that can be applied to the design, construction and maintenance of roofs.

CONCLUSION

Roof condition indices (RCI) were calculated by MicroROOFER from the visual inspection of roofs on the University of New Brunswick=s Fredericton campus. Roofs less than 10 years of age are deteriorating at a faster rate than older roofs on the same campus as indicated by lower roof condition indices. This could be due to several factors:

- the lack of quality management in design and construction (poor materials and methods)
- a lack of a roof maintenance management system
- a lack of funding for maintenance expenditures

The reason for the lower RCI is most likely to be due to a combination of one or more of these factors.
The following recommendations summarize suggested improvements to the University of New Brunswick=s quality management program:

- institute pre-qualification requirements for A/E roof designers and contractors
- improve the quality assurance program by hiring a third-party quality control inspector
- implement a roof maintenance management system
- utilize MicroROOFER as a tool for maintenance, repair, and replacement decisions
- allocate 2 to 4 % of the replacement value of the roof as an annual budget for roof maintenance and repairs

The implementation of a quality management program will aid in preventing inadequate design, materials, workmanship, and maintenance.

REFERENCES

[1] Bailey, D.M., Adiguzel, I. (1999) Improvement Opportunities in Roofing Assets Management: Experience from the US Army. Durability of Building Materials and Components 8 (Lacasse, M.A., Vanier, D.J., ed) 1193-1202, NRC Research Press, Ottawa, Canada.

[2] *Bailey, D.M., Brotherson, D.E., Tobiasson, W., Foltz, S.D., Knehans, A.* (1993) ROOFER: Membrane and Flashing Condition Indexes for Single-Ply Membrane Roofs - Inspection and Distress Manual. USACERL Technical Report FM-93/11.

[3] *Bailey, D.M., Brotherson, D.E., Tobiasson, Knehans, A.* (1990) ROOFER: An Engineered Management System (EMS) for Bituminous Built-Up Roofs. USACERL Technical Report M-90/04.

[4] *Froese, T. M., Hassanain, M. A., Vanier, D. J.* (1999) Information analysis for roofing systems maintenance management integrated system. 8th International Conference on the Durability of Building Materials and Components.

[5] *Lounis, Z., Vanier, D.J., Lacasse, M.A., Kyle, B.* (1998) Effective Decision-Making Tools for Roofing Maintenance Management. Proceedings of the First International Conference on Information Technologies for Decision Making in Construction (Miresco, E.T., ed) 425-436, Montreal, Canada.

[6] *Lounis, Z., Vanier, D.J., Lacasse, M.A., Kyle, B.* (1999) Decision-Support System for Service Life Asset Management: The BELCAM Project. Durability of Building Materials and Components 8 (Lacasse, M.A., Vanier, D.J., ed) 1223-1234, NRC Research Press, Ottawa, Canada.

[7] *Schneider, K.G. Jr., Keenan, A.S.* (1997) A Documented Historical Performance of Roofing Assemblies in the United States 1975-1996. Fourth International Symposium on Roofing Technology. 132-137.

[8] *Shahin, M.Y., Bailey, D.M., Brotherson, D.E.* (1987) Membrane and Flashing Condition Indexes for Built-Up Roofs. USACERL Technical Report M-87/13. 2.

[9] *USACERL.* (1995) MicroROOFER, Version 1.3. U.S. Army Corps of Engineers, Construction Engineering Research Laboratories.

[10] Vanier, D.J., Lacasse, M.A. (1996) BELCAM Project: Service Life, Durability, and Asset Management Research. 7th International Conference on the Durability of Building Materials and Components. 2, 848-856.

IMPLEMENTATION OF KAIZEN IN THE CONSTRUCTION ENTERPRISE

S. García Rodríguez; J. C. Horita Figueroa
ITESM Campus Monterrey, México
salvgarc@campus.mty.itesm.mx

The purpose of this work is to make a contribution to the construction enterprise about concepts, practices and tools in the field of the total quality management, specifically, inside of continuous improvement (kaizen), since the quality practices in the construction environment has been limited to the inspection of the final product (at list in Mexico). From this perspective the construction enterprise can not continue giving itself the chance of stay behind in this field. Thus, every effort to advance in this sense will be useful in the construction enterprise. Specially in this time in which the rule is the change and the globalization constitute an international competition stage with world class practices.
This necessity of compete satisfactory inside international markets makes quality a determinant factor, thus it is proposed kaizen approach as an alternative that allow a successful introduction of total quality minimizing frustration.

The necessity of competing satisfactory inside international markets makes quality a determinant factor. Having as the most important objective of quality the satisfaction of customer expectations and even go beyond them.

The creation of a quality culture for an enterprise which is trying to survive in these days must exist in the entire organization and in every activity developed. Once this culture has been adopted works as a motivator to the employees with great benefits.(Bermudes, 1997)

Some of those benefits are:

Internal

- Quality improvement of the product or service
- Enhance of productivity
- Diminish of costs
- Enhance of profit

External

- Customer satisfaction
- Enhance of market share
- Customer loyalty
- Prestige

So far it has been said one of the two more important elements for the implementation of total quality in an enterprise the adoption of a quality culture, the other one would be people (human resource).(Cane, 1997)

It is relatively easy identify if row materials or equipment present deviations, however, the human factor is the most fragile link of the productive chain. Thus a good total quality program must foment the development and maintenance of skills, knowledge and attitude of people.

¿What is quality?

Inside the construction field quality can be defined as the actions directed to design, built and maintain a construction project to be the most economic, the most functional, always fulfilling customers expectations. (Ishikawa, 1997)

Total quality consist of three main elements:

1. It is customers oriented
2. It is focused to the continuous improvement in every aspect of the organization
3. It involves everybody

The concept of "KAIZEN"

First of all KAIZEN can be defined by its japanese words: Kai means change and Zen means good then it means a good change or improvement, But kaizen goes beyond, it is progressive improvement that involves executives and workers. Kaizen use management tools that have proved their efficiency like quality circles and suggestions system.(Imai, 1996)(Nihon, 1992)

A kaizen strategy maintain and improve standards through gradual and little improvements. Maintenance means the activities directed to continue with the current standards be it managerial, be it operational. Improvement refers to those activities focused to raise the current standards.

Under maintenance functions. Management do their assignments in such way that everybody in the company can follow the established standard. This mean that management first must establish politics, rules and procedures for every important operation and then verify the execution of those standards. If people is capable to follow the standards but they do not, managers bust apply discipline. On the other hand if people in the company can not follow the standard, trainmen should be given or the standard should be reviewed. Improvement refers to the elevation of the standards. Long lasting improvement can be reached when people work for higher standards.

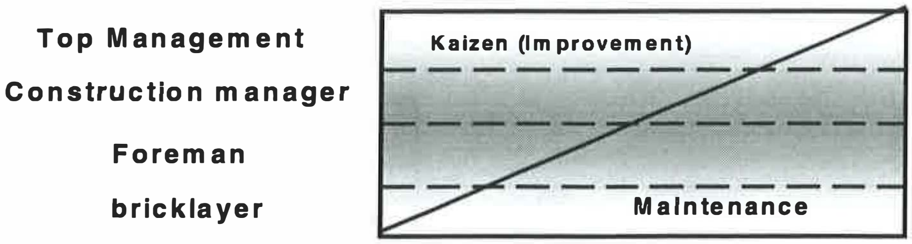


Figure.1 Improvement and maintenance (Imai, 1996)

Improvement can be divided in two parts KAIZEN and innovation, where kaizen refers to little improvements in the status quo as a result of progressive effort. Innovation implies drastic improvements as a result of big investments in technology and equipment.

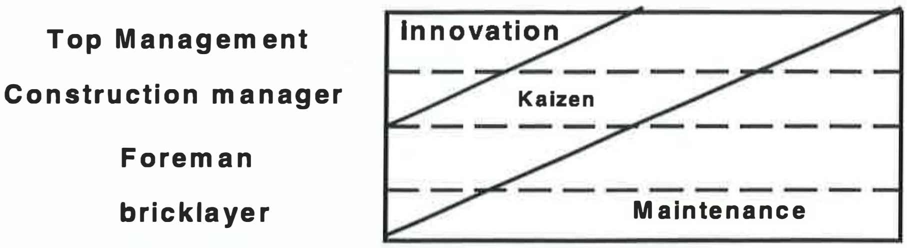


Figure.2 Innovation, kaizen and maintenance.

Improvement starts recognizing its necessity through the identification of a problem. If no problem is recognized then there is no necessity of improvement. Complaisance is the enemy of continuous improvement. In consequence it is emphasized the identification of problems.

The improvement reach new levels with every solved problem. However, in order to consolidate the new level it must be standardized. Continuous improvement require standardization and its consequent documentation.

Kaizen and Innovation

As it has been indicated before innovation is observed as big changes thanks technological progress, new management techniques or new production styles. In contrast, this improvement style just needs conventional and easy techniques with low cost of application (cause and effect diagrams, Pareto charts, quality circles, suggestions systems and so on). However big amount of effort has to be applied.(Imai, 1998)

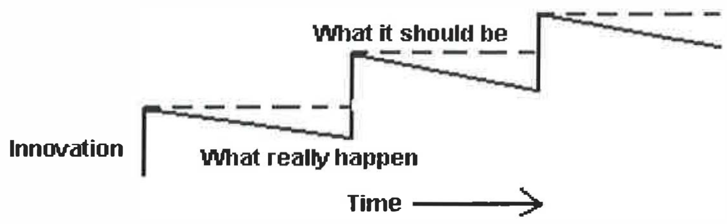


Figure.3 Real innovation trend (Imai, 1998)

Figure.4 Innovation plus kaizen (Imai, 1998)

It may be said that innovation resemble to an ascendant stair which suffers deterioration in the short term. In reality there is no static constant, every system is destined to deterioration once it has been established. However, it should even exist a progressive improvement effort to maintain the status quo. Capital injections do not substitute time and effort investments. Invest in Kaizen is about investing in people.

This philosophy is better adapted to slow growing economies, (like those of Latin American countries) while innovation is better adapted to fast or sustained growing economies.

The suggestions system

The suggestions system is a contribution of kaizen to involve employees inside the continuous improvement activities. This tool has its foundation in the fact that the employee is who face the problems in the work place. Been him who can create feasible solution alternatives. This way the person in charge function is diminished because it is not him who need to contribute with solutions to specific problems in the work place, be it office be it field. (Cane, 1997)

The main suggestions themes may be:

- Improvements in the execution of self work
- Energy, materials, time and transportation savings .
- Improvements of the close work place
- Process improvements
- Tools improvements

- Coordination office-field improvements
- Functional areas communication improvements

The execution of those suggestions after reviewing them is a must. This way the employee is encouraged to continue with suggestions emission. On the other hand is a good way to make feel the employee that their contributions are useful to the organization.

It is necessary create a reward system for every implemented suggestion. The reward has to be proportional to the impact gotten with the implementation of the suggestion.

Some examples of rewards are:

- Pens with the company logo
- Show tickets
- Cash rewards
- Travels to other plants to give training
- Public recognition in news blackboards

Monitoring the suggested improvement

Once the improvement plan is in practice a monitoring of the results must take place. It is very important prove weather the actions took fulfill the wished goals. At the beginning every improvement is unstable. A stabilization period should be considered through a process known as Plan-Do-Check-Act (also known as Deming´s cycle). The cycle's goal is to maintain the effectiveness of the improvement reached before. These are the main responsibilities of the high management.

In order to get the better results of the application of the Deming´s cycle, every person in charge of continuing the improvements should carry out the four steps of the cycle. Likewise, it has to be remembered that the cycle get the better results after the four steps are done several times for one single improvement before it reaches stability.

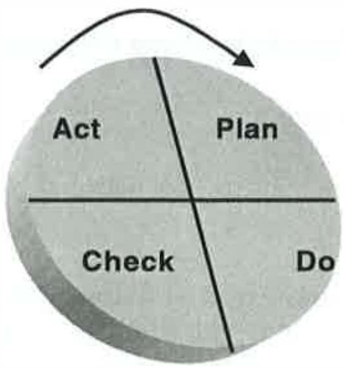


Figure.5 Deming´s Cycle

Working with small groups (Quality Circles)

Several definitions exist about what a quality circle is, among them:

Small groups of persons who meet periodically (once a week) to detect, analyze and seek for solutions of problems at the work place.

Every quality circle should concern itself with several problems related with a specific theme which match the mission and vision of the entire company. The next sequence is recommended.

1) Chose a theme (to set goals)
2) To explain the reasons of choosing those goals
3) To evaluate the current situation
4) To analyze (causes research)
5) To establish corrective measures and execute them
6) To evaluate the results
7) To standardize
8) To document
9) To consider the remain problems
10) Future planing

METHODOLOGY

Once it has been explained the total quality and the kaizen basics, it will be showed a practical application of this concepts and tools inside a construction enterprise of Monterrey, Nuevo Leon, Mexico. For this purpose, it was carried out instruction sessions toward construction managers, foremen and superintendents. Ending with an exercise of a quality circle about a detected problem.

Pilot program "kaizen"

The next activities plan was carried out to develop kaizen`s pilot program.

A survey was done to know the total quality level into the enterprise.
Instruction about kaizen and tools
Solutions plan to a detected of a problem

The sessions were integrated with the construction manager, foremen, superintendents and a methodological facilitator.

The handling of the detected problem was worked following the quality circles methodology, however, the meetings were conducted not with first line workers but with the manager and the foremen. It seams to an improvement circle but was thought this way to

Facilitate the acquisition of the quality circles methodology
Educate future quality circles instructors to work with first line workers.

Diagnosis

The first step of the plan established before was a survey to realize the total quality level into the enterprise. The next figure is the result of this.

Figure.6 Total quality level

It can be noticed that the strategic planning -a fundamental sector- has been left behind. In this department it is considered the set of actions directed to positioning the enterprise in the place that the mission and vision establish in the long term.

Materials supply improvement opportunities

The materials supply was detected as an improvement necessity. This deficiency include materials and pieces delays and incomplete deliveries. The consequences about the lack of materials in situ are well known among them we can remark :

- Finishing dates delays
- Labor can not continue doing piecework and their income is reduced in consequence.
- Before this situation labor decide to emigrate to other constructions
- New labor frequently is more expensive and the apprenticeship curve do not allow a sustained working rhythm.
- The delays and the elevation of costs damage the company reputation

To determine the causes that produce materials supply errors a fishbone diagram was built.

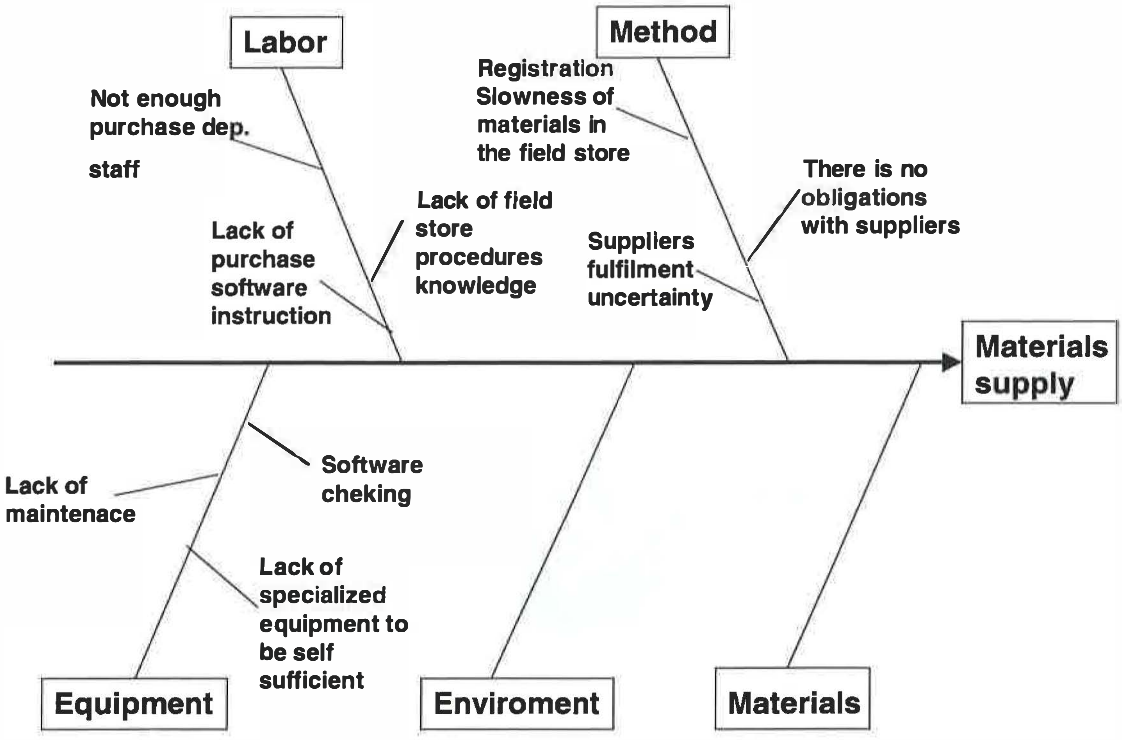


Figure.7 Fishbone diagram (cause and effect)

Some suggestions from the above set of causes were:

Related to the method
- Potential suppliers table of comparison
- Establishment of agreements with selected suppliers
- Verification calls to match information about shipments
- Ask for concrete morning deliveries to reduce risks of delays

Related to the labor
- Since expansion perspectives are considered it is necessary to recruit personnel to the purchase department.
- Purchase software training
- Reception and registration material training (in situ)

Related to the equipment
- Acquisition of a concrete truck to reduce dependence with the concrete supplier.
- If this is not possible in the short term look for rent that kind of trucks.

RESULTS

Table I: Corrective measures planning chart (materials supply)

What	How	Who	When	Performance measure
Reduce the non-fulfillment supplier uncertainty	To Call in advance to confirm	Purchasing person in charge	Anytime, depending of the supplier reputation	Material required Material delivered
To establish agreements with several suppliers	Setting meetings with suppliers to establish necessities and expectations	Purchasing department and management department	Before the start of any construction project	Number of agreements settled. Number of delays.
Enhancing the velocity of registration and reception of the warehouse material in situ	More warehouse assistants and trainning	Warehouse chief	During the construction	Information flux time (warehouse-office)
To know the in situ warehouse materials procedures to coordinate efforts	To visit several company's construction warehouses	Purchasing chief	During the execution of every construction	Coordination failure
New people recruiting and instruction	Giving promotion to warehouse personnel	Purchasing chief	Any time	Coordination warehouse-purchasing department
New materials suggestions to the client	Enhancing communication with client	Purchasing person in charge	Materials scarcity	It does not apply
To standardize in situ warehouse procedures	Warehouse procedures training	Warehouse chief, several construction places	To start immediately	Number of persons trained

Specifically, a 2o.floor system material delay was detected in one of the "in progress" constructions. The repercussion of this situation was in the entire advance of the construction, as it can be seen in the next report. In the first report it can be seen an looseness until the 2o. floor system had to be placed.

PROJECT. HACIENDA LOS LERMAS
MANZANA: 44 (DEL LOTE 01 AL 17 Y DEL 20 AL 38)
CONTRATISTA :
DATE: 13/ MAY/ 2000

CODIGO	CONCEPTO	FREIGHT No	PROGRAM PROGRESS	PREVIOUS PROGRESS	PRESENT PROGRESS	THIS WEEK PROGRESS	DIFERENCE
52-01	DIGING	36	ok				
52-02	FOUNDATION AND FLOOR	36	ok				
52-03	FOUNDATIONS UTILITIES	36	ok	ok			
52-04	WALLS FIRST FLOOR	36	32		36		4
52-05	COLUMNS	36	29		31		2
52-07	PRESTRESED SLABS 1ST FLOOR	36	24		28		4
52-08	STAIRS	36	24		28		4
52-09	WALLS SECOND FLOOR	36	22		23		1
52-10	COLUMNS SECOND FLOOR	36	22		20		-2
52-12	PRESTRESED SLABS 2ND FLOOR	36	18		16		-2
52-13	2ND LEVEL UTILITIES	36	18		16		-2
52-14	INSULATION	36	8		0		-8
52-15	TILING	36	15		8		-7
52-16	EXTERIOR WALL FLATTENING 1FT FLOO	36	13		6		-7
52-17	INTERIOR FLATTENING 1ST FLOOR	36	13		5		-8
52-18	EXTERIOR WALL FLATTENING 2ND FLOO	36	13		6		-7
52-19	INTERIOR FLATTENING 2ND FLOOR	36	13		5		-8
52-21	RAILING	36					0
52-22	CONCRETE WASH TABLE	36	12		0		-12
52-23	PAINTING	36	12		5		-7
52-24	SIDE WALK	36	12		0		-12
52-25	EXTERIOR WALLS	36	9		0		-9
52-26	LITTLE WALLS	36	9		0		-9
52-28	WINDOWS	36	12		5		-7

Figure 8. Schedule Progress Reports

OBRA. HACIENDA LOS LERMAS
MANZANA: 44 (DEL LOTE 15 AL 38)

24 viviendas

CODIGO	CONCEPTO	week	8	9	10	11	12	13	14	15	16	17	18
		Month	MAY					JUNE					
		Day	01-06	08-13	15-20	22-27	29-03	05-10	12-17	19-24	26-01	03-08	10-15
52-01	DIGING				ok								
52-02	FOUNDATION AND FLOOR				ok								
52-03	FOUNDATIONS UTILITIES				ok								
52-04	WALLS FIRST FLOOR				ok								
52-05	COLUMNS				ok								
52-07	PRESTRESED SLABS 1ST FLOOR				ok								
52-08	STAIRS				ok								
52-09	WALLS SECOND FLOOR				ok								
52-10	COLUMNS SECOND FLOOR				ok								
52-12	PRESTRESED SLABS 2ND FLOOR				ok								
52-13	2ND LEVEL UTILITIES				ok								
52-14	INSULATION												
52-15	TILING				-5								
52-16	EXTERIOR WALL FLATTENING 1FT FLOOR				1								
52-17	INTERIOR FLATTENING 1ST FLOOR				-1								
52-18	EXTERIOR WALL FLATTENING 2ND FLOOR				-5								
52-19	INTERIOR FLATTENING 2ND FLOOR				1								
52-21	RAILING												
52-22	CONCRETE WASH TABLE				-8								
52-23	PAINTING				5								
52-24	SIDE WALK				-6								
52-25	EXTERIOR WALLS				-4								
52-26	LITTLE WALLS				-2								
52-28	WINDOWS				2								

As it can be seen in the second report the delays in some of the concepts begin to be compensated. The accurate participation of all the actors involved will allow the recuperation of the schedule. On the other hand the recognition of the causes is a must to avoid future mistakes.

CONCLUSIONS

It is fundamental that the PDCA cycle be executed several times before the planed solutions get sharp, after that it is required that those new practices become part of the standard procedures through documentation.

The example presented constitute the beginning of KAIZEN operations through the activity of quality circles. After the improvement planning chart is prepared, the performance monitoring is a responsibility of the medium section management through the application of the performance measures. The consolidation of such kind of plans will be seen in the long term.

Specifically, talking about the employee participation inside the improvement efforts, It has to be remark that the systemization of the actions in several organized steps allow less process variability. Probably in several organizations, this activities are carried out in an intuitive way, or due to general management knowledge, however ignoring the system leads problem detection and analysis in a discretionary way. Total quality management (TQM) and kaizen struggle with the direction stile by “feeling”.

In order to reach success with the employee participation, the management has to foment the kaizen activities through an incentive system. The medium management has to know very well the methodology and its goals. Likewise, top management has to get involved with kaizen activities designating resources, conceding rewards and recognizing kaizen efforts.

Finally, quality circles participants must understand that the roll of the methodology facilitator is to serve as a guide of the application of techniques, tools and concepts related to Kaizen and TQM, not to propose the improvements to posed problems.

REFERENCES

[1] Bermúdez, R, Los costos de la calidad en la industria, IMCYC
[2] Cane, Sh. (1997) Cómo triunfar a través de las personas, Mc Graw Hill, Colombia
[3] Hammer, M. And Champy J., (1994) Reingeniería, Norma, México
[4] Imai, M, (1996), Kaizen, La clave de la ventaja competitiva japonesa, CECSA, México
[5] Imai, M, (1998), Cómo implementar el kaizen en el sitio de trabajo, Mac Graw Hill, México.
[6] Ishikawa, K., (1997) ¿Qué es el control total de calidad?, Norma, México.
[7] Nihon K, (1988) The Idea Book, Productivity Press, Cambridge.
[8] Nihon, K, (1992) Kaizen Teian, Productivity Press, Portland
[9] Sigh S., (1992) Total Quality Control Essentials, key elements., Mc Graw Hill, U.S.A.

THE STUDY OF MARKET AS COMPETITIVE STRATEGY IN THE CONSTRUCTION OF HOUSING

Salvador García Rodríguez, Sergio Alberto Acero Pérez
ITESM Campus Monterrey, México
salvgarc@campus.mty.itesm.mx

The sector of the construction is especially one of the few ones that has presented a sustained growth inside the construction industry in the last years, the field of the housing of social interest it has been strongly impelled because it is an important factor of economic development joined to the demand growing of workers for the acquisition of a house. The companies dedicated to the construction of this housing type face problems like the strict cost control due to the reduced sale price, constructive practices not very efficient, manpower shortage and a high competition due to the great quantity of constructors that have seen in the business of the housing of social interest the form of remaining active in the industry; however little attention has been paid to the integration of the promotion departments and construction to generate information that allows them to feedback their functions and to develop or to improve their products according with the market demand. The investigation of markets is a methodology that allows the approach of the clients with the organization through the information; it identifies and it defines the opportunities and problems of the business specifying the type of information that is required, it designs the most appropriate method for its collection, it instruments the process of gathering of data, it analyzes the results and it presents the discoveries and recommendations. The present work is carried out a market study for a construction company of the region where strategic aspects are analyzed as the market participation, the characteristics of the housing, the offered services and the competitive advantages of the company and their main competitors; technical aspects are also studied as the defects that were already presented in some habited residence developments, as well as the perception of the users about the size and quality of the housing or the security of the residence development. From the result of the study we derived the recommendations proposed to the company so that it establishes strategies of competitiveness and improvement in future projects.

The focus of the total quality has been adopting in a general way in the industrial sectors and in services like a way of facing the competitiveness taken place by the opening of economies to the commercial exchanges. The construction industry is not unaware to this phenomenon, however the lack of quality has been the common denominator of the constuction companies due to the lack of creativity of the sector to adopt and to adjust the principles and tools of the quality in the execution of the administrative and operative processes that involve a construction project. (Acero,2000)

Due to the low growth of the field of the construction caused by the investment lack in public work and infrastructure and to the historical deficit in the housing production that is considered at the moment in 5,200,000 housings according to SEDESOL, it makes the field of the housing especially that of social interest, an important niche of market in which several constuctors have intruded or they have recaptured again and that obligue to the companies that were dedicated already to this field, be forced to improve the offer of their products to be able to stay competitive.

The philosophy of the Administration for Total Quality applied to all the stages of a construction project will allow that a company establishes its strategies according to its environment, have as daily task the continuous improvement and impact its utilities in a positive way achieving its permanency in the market. Besides the improvement of the internal processes of the company that allows to control them and to assign resources in a more efficient way, the organization should adopt one of the fundamental principles of this philosophy: the satisfaction of the client. (Sarv, 1992) (García, 1999) (Omachonu, 1995)

The administration for total quality and the marketing are similar and complementary philosophies, with an external focus in the satisfaction of the client and an internal focus in the excellence of the operation, the marketing function in an organization should take to establish the true requirements of the product or service. When having determined the necessity, the marketing should define the sector and the demand of the market to decide the characteristics of the product or service, such as class, price, quality and times of delivery . (Sarv, 1992) (Kee-Hung, 1998)

The marketing will also need to establish the requirements of the clients revising the necessities of the market in terms of expectations and basic characteristic that determine the convenience of the product or service to the eyes of the client. To achieve this it requires the use of technical of investigation of markets, benchmarking, gathering of data and analysis of the clients' complaints (Oakland, 1999)(Kotler, 1996) (Lamb, 1994) (Spendolini, 1994)

The importance of the investigation of markets has been increased in the last three decades. The new orientation toward the quality of the products and the services on the part of the organizations has put emphasis in the investigation of markets for the identification of the necessities of the consumers and in the measurement of the satisfaction of the same ones.

The investigation plays a paper of multiple implications in the process of the marketing management, that which includes the active participation of the investigation in the process of taking of decisions, with special emphasis in the supply of significant information for the planning and control functions. The purpose of this source of information consists on to reduce the error in the taking of decisions and to enlarge its perspective; the best decisions should be the result of the use of better sources of information.(Kinnear, 1998)

In this definition they are included characteristic or essential elements of what constitutes an adequate investigation of markets, they are: systematic, information and taking of decisions. The investigation of markets is systematic, because it is required that the investigation project is very organized and planned, the strategic aspects of the design of the investigation should be detailed ahead of time and also to be early the nature of the data to gather and the analysis way to use. The two remaining elements of the definition are information and taking of decisions that differentiate the investigation of markets of the investigation in other areas; the main purpose of the investigation of markets is to provide information, for the process of taking of managerial decisions.

The formal project of investigation of markets consists on a series of six steps (Figure 1), in them, it is defined the activities that should be carried out to achieve an investigation study; for the definition of the problem it should be kept in mind the purpose of the investigation, to define what information will be necessary and how it will be used for the taking of decisions, to accomplish this stage discussions can be included with those that make decisions, interviews with experts of the industry or the analysis of secondary data. (Malhotra, 1997)

Once the problem has been defined; the investigator will formulate the objectives of the investigation (Development of a position of the problem) and to elaborate a specific list of the necessities of information; the objectives of the investigation should be presented in writing before carrying out the project. (Malhotra, 1997) (McDaniel, 1999)

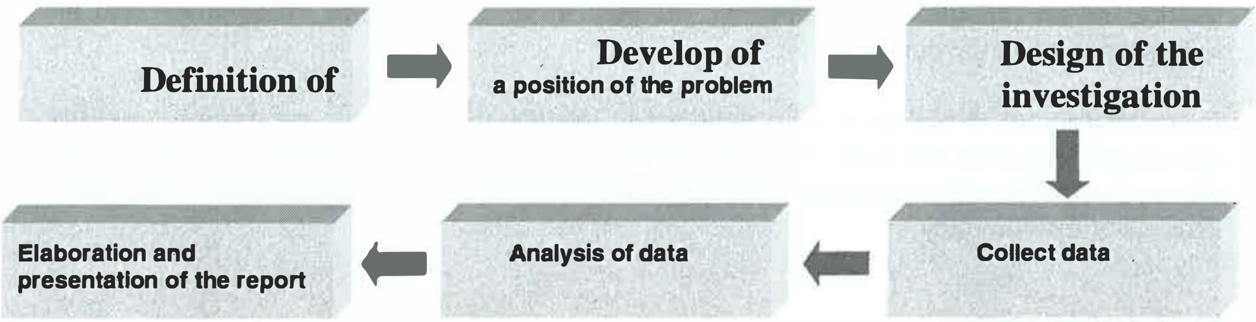


Figure 1. The process of the investigation of markets.

In the design of the investigation, the necessary procedures are detailed to obtain the required information, it specifies the type of information to gather, the sources of data and the procedures and analysis of the collection of data, with the purpose of designing a study that proves the hypothesis that interests us, that determines the answers to the questions that are being investigated and provide the necessary information for the taking of decisions. The establishment of an investigation design includes the following steps:

1) Analysis of secondary data
2) Definition of the necessary investigation
3) Mensuration procedures and scales
4) Design of questionnaires
5) Sampling process and sample size
6) Planning of the analysis of data

The collection of data is carried out by a working team that operates indistinctly in the field, like it is the case of the interviewers; the selection, supervision and training of the personnel in charge of driving these interviews help to reduce the errors in the collection of data. Once the data are obtained a preparation work it is needed that includes their edition, code and verification. Each questionnaire is revised and when it is necessary, it is corrected; codes of numbers or letters are assigned for each question of the questionnaire. The data are verified to assure that the data of the original questionnaires are transcribed thoroughly and accuracy, while the analysis gives meaning to the gathered information. (Malhotra, 1997)(Blankenship, 1998)

The whole investigation study will be documented in a written report that presents in a specific way, the questions that were identified during the investigation; the position of the problem and the objectives of the study, the collection of data and the procedures for its analysis, as well as the presentation of the results and more important discoveries.

In this work the methodology of the investigation of markets was applied in a competition study to obtain the characteristics of the product that different companies dedicated to the construction of housing of social interest offer and to know the market percentage in which each one of them participate. Additionally it was carried out a study of satisfaction of the users of housings in residence developments of different companies of the region, analyzing aspects like: the factors that impacted in their purchase decision, the appreciation of the quality and functionality of the housing, the security of the residence development and the service granted by the company.

In the analysis of the information it is hoped to identify the profitable opportunity areas for the company to adapt the product and the offered service to the real necessities of the market; the analyzed data will concentrate on recommendations that can be implemented in the future projects of the company.

METHODOLOGY

For the realization of the market study the methodology pointed out in the figure 1was followed, where the definition stages and position of the problem were defined jointly with the management of the construction company where the necessities of information concentrated on the following specific objectives for the investigation:

1) The primordial characteristic of the companies to compete in the market of the housing.
2) The services that provide the companies competitors to their clients.
3) The total offer of housing in the different residence developments.
4) The characteristics of the housings of the competition relating to price, land surface, size of the housing and the type of finishes that they offer.
5) The percentage of the market with which participates each company
6) Areas of improvement in future projects

Casas Geo, Vidusa and Consocio Hogar were the companies that identified as García's Villareal direct competition; where the study was applied. For the collection of the primary information two questionnaires were designed; one of them managed to the executive staff, preferably of the marketing area or sales in which are included questions that cover the necessities of information on the following points:

1) Current offers of housing
2) Characteristic (construction surface, finishes, sale price, etc.)
3) Use of marketing tools (publicity, investigation of markets)
4) Market participation

The second questionnaire was used for the analysis of satisfaction where was necessary to identify the characteristics that have bigger weight so that the user of a credit opts for a type housing in particular and that simultaneously it measured the grade of satisfaction of such attributes as the quality of the construction, the service granted by the company, the size and the location of the housing, the security of the residence development and the types of defects that presented the housing.

The qualification scale that was used to measure the grade of satisfaction of the users includes the following categories:

Excellent	**Good**	**Satisfactory**	**Bad**	**Very Bad**
5 points	4 points	3 points	2 points	1 point

The sampling procedure for the application of the surveys was made in a random way, the sample sizes" n" in the different residence developments they are shown in the table I

Table I. Sample size to make the study of satisfaction.

Size of the Sample " n"	Residence development	Company
34	Fuentes of Escobedo	García Villareal
38	Prados del Virrey	Geo
39	Residential los Ebanos	Vidusa

It fits to point out that in the residence development of the company Consorcio Hogar it could not be carried out the analysis of satisfaction because there were not enough users habiting the housings, for what the information that one could recabar would not be representative of the residence development.

RESULTS AND DISCUSSION

The result of the competition study was concentrated on a comparative table (Figure 2) showing the results from the questionnaire applied to the sales or marketing managers of each one of the companies; from this table it stands out the cost for square meter of construction of the companies competitors which is a starting point to establish the sale price of the housing, the percentage of market participation allows to plan the promotion strategy and commercialization of the product, besides locating the areas of the city where at the moment the different residence developments are promoting.

	García Villareal	Geo	Consorcio Hogar	Vidusa
Competitive advantage MAINTEN ANCE	The being established company with wide experience in the housing construction	Originality in the design. It promotes the urban group of the division (school, sport courts, business district)	Attention to the client. speed in the delivery of the housing. traditional construction	The constructor's recognition. Experience in the housing construction
Services	Consultantship in the housing purchase and procedure of the credit After-sales service in the repair of the housing for one year	After-sales service and client attention housing for one year guaranteeing 1 day to check that the specified characteristics surrender to the client 3 months in defects not caused by the use 1 year waterproofing.	Gratuitous procedure of the credit INFONAVIT	Guarantee of one year in all type of repairs (facilities, doors, locks, waterproofing) PLAN FIRST Journey to show the residence developments that offer.
Divisions Offer	98 Escobedo 144 Apodaca 39 Juárez	1034 Sta. Catarina 819 Villa de Juarez	250 Cd. Solidaridad 230 Escobedo 225 Huinala 130 Sta. Catarina	425 Guadalupe 345 Juarez 595 Apodaca
Total of Housing	281	1853	835	1365
Characteristic of housing				
Land Surface	90m²	72 m²	90 m²	90 m²
Construction surface	58.00 m²	56.34 m²	64.45 m²	55.86 m² 69.61 m² 51.56 m²
Type of finishes	Interior plaster, interior and exterior painting, floor of refined cement.	Plaster, floor of refined cement, paint in some walls, tile in bathroom. PLAN GRAPHIC	Interior plaster, painting on front, floor of refined cement, insulating thermal in facade.	Vinyl floor, insulating thermal in facade. Interior and exterior painting.
Price of sale	$167,000	$180,000	$192,500	$150,000 $180,000 $145,000
Cost per m²	$2,879.31	$3,194.89	$2,986.81	$2,694.46
Publicity On promotion	Press, visit to companies Module of information.	Radio, television, triptych, press, spectacular announcement.	Radio, television, press, information modules.	Television, Press, triptych.
Type of investigation of market	Informal method to sound the market	Investigation of the product and of the competition upgrading it every two months.	It doesn't carry out any type of market investigation.	Mensuration of the client's satisfaction hidden buyers
Sales during 1999	225	1700	800	1232
Sales to the first trimester of 2000	52	640	100	400
Industry value *	19,740	19,740	19,740	19,740
Market participation	1.14%	8.61%	4.05%	6.24%

(*) **Source:** Asociación de Desarrolladores Inmobiliarios y de Vivienda de Nuevo León, A.C. (ADIVAC).

Figure 2. Summary of the competition study and market participation.

In the following tables the results of the study of satisfaction of the users are presented; being 5 the maximum qualification perceived as "excellent" for an user, it would be expected that the averages of the applied questionnaires to people oscillated between 4 and 5, the following table (Table II) presents the averages of the grade of people's satisfaction with regard to the location, service, size, quality and security of the housings in the analyzed residence developments of each one of the constuction companies.

Table II. Summary of the grade of satisfaction of the users in the different residence developments.

	Location	Service	Size	Quality	Security	Total
Geo	**2.84**	4.08	3.32	3.24	**2.71**	**3.24**
García Villareal	4.06	4.32	**3.41**	3.65	**3.09**	3.71
Vidusa	**3.74**	4.28	4.03	**3.74**	3.77	3.91

In the figures 3 at 5 the dispersion diagrams are presented that allow us to compare the evaluation of the satisfaction that has each company regarding their competitors and the importance that it has in particular for the users each characteristic.

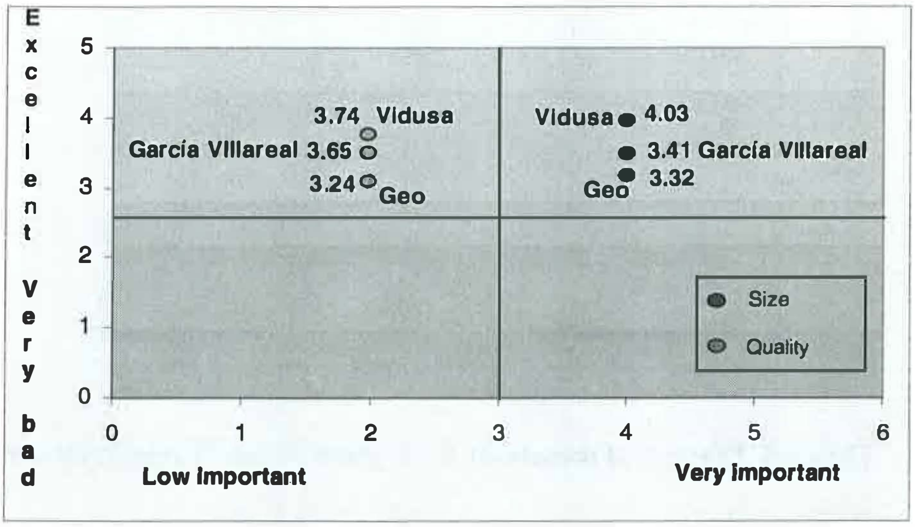


Figure 3. Diagram of dispersion of the grade of satisfaction in the size of the housing and the quality of the construction

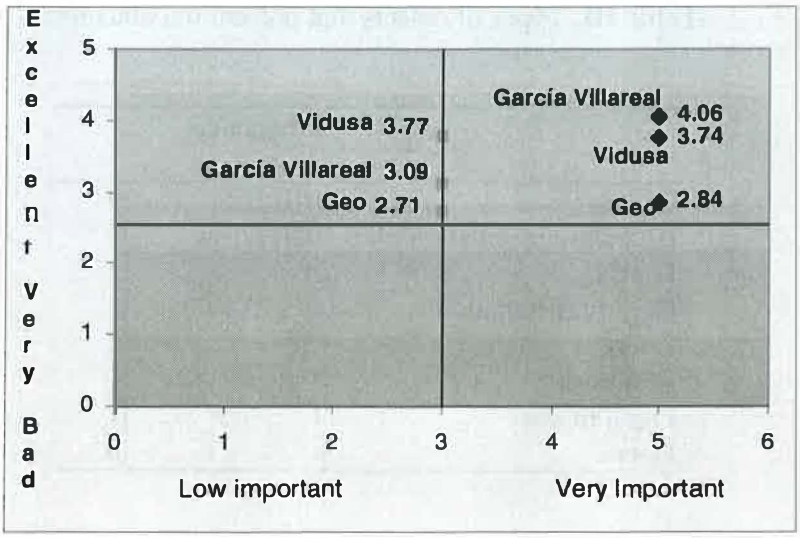


Figure 4. Diagram of dispersion of the grade of satisfaction in location and security of the residence development.

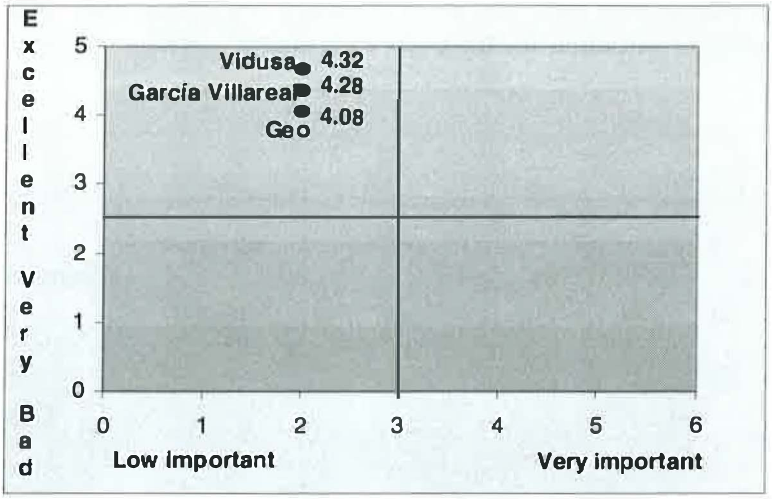


Figure 5. Diagram of dispersion of the grade of satisfaction in the service.

The table III show the distribution of frequency of the types of defects that were presented in the housings, in a complementary way a diagram of Pareto is presented (Figure 6) where is observed that solving the cracking problems, facilities and finishes, 80% of the constructive defects is eliminated in the residence development.

Table III. Types of defects that present the housings.

	Frequency	
Cracks	IIIII IIII	9
Hydraulic installation	IIIII I	6
Finishes	II	2
Electric installation	II	2
Leaks	II	2
Windows	I	1
Flight of gas	I	1
Doors	-	0

The part of the housing that the users consider that it is very small and in the one they need bigger space it is the room followed by the chambers, this information can be used like entrance fact for the design department. The distribution of frequencies of the parts of the housing where the clients need bigger space is shown in the figure 7.

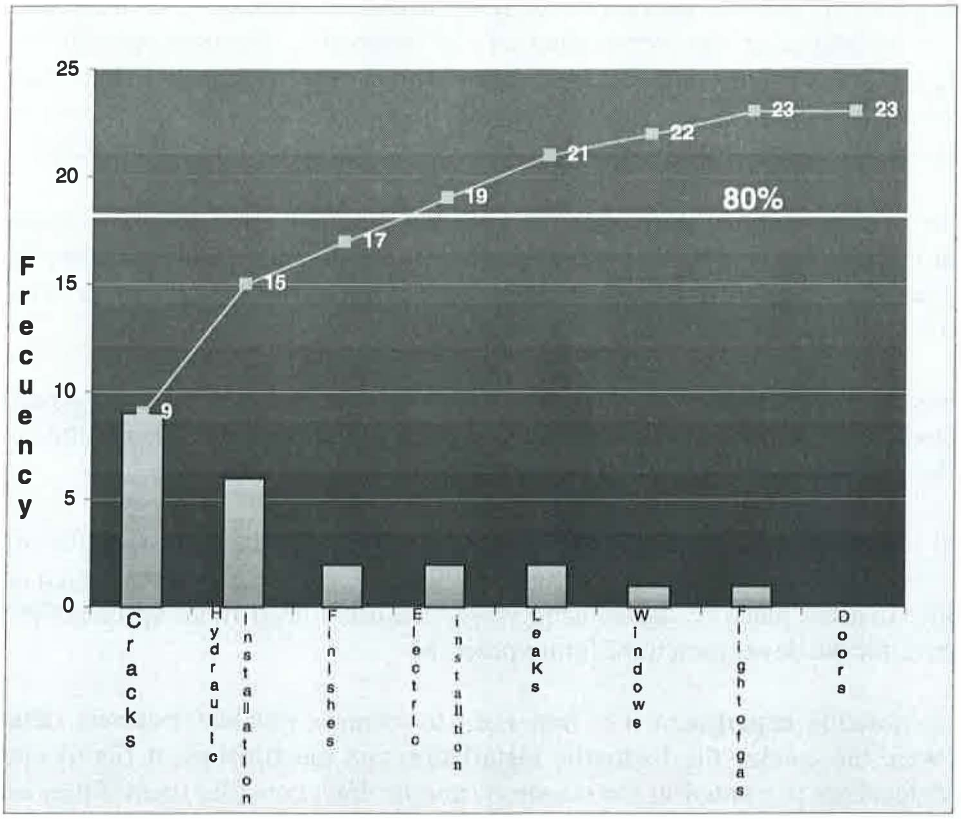


Figure 6. Diagram of Pareto of the defects that present the housings.

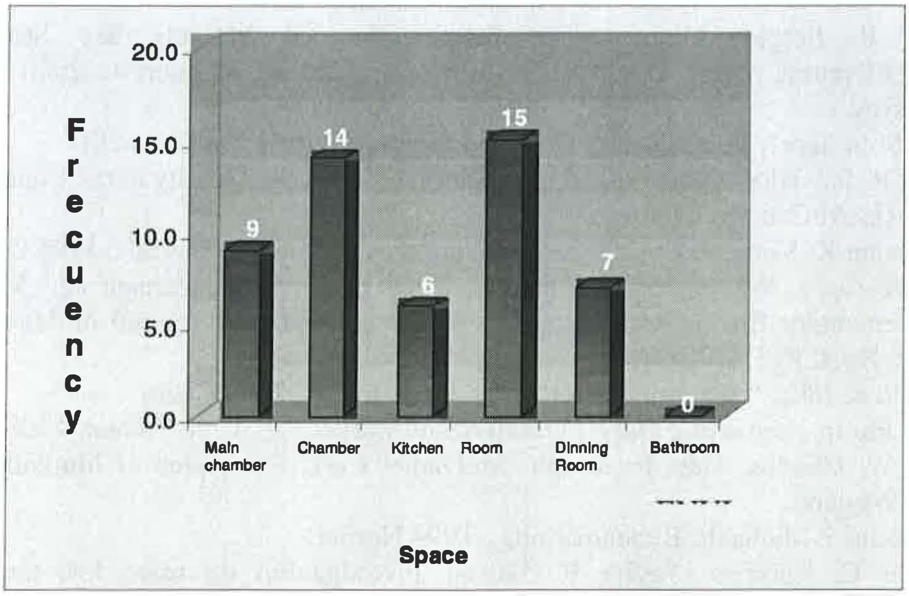


Figure 7. Place of the housing where the users need more space.

CONCLUSIONS

The investigation of markets applied to the construction of housing of social interest, has the potential of coordinating the information of the promotion departments and construction stablishing market strategies and developing products in agreement with the necessities of the client. Additionally it stands out the fact that the analyzed information can serve as entrance to improve operative processes like the design and the supervision of the housings.

In the case of this study in particular the creation of a corporate image is recommended, toward the market that allows the potential clients to identify the residence groups that offers the company, stablishing strategies of commercialization more aggressive tendientes to increase the participation of market of the company.

The studies of the profile of the clients, tendencies of the market, mensuration of the effectiveness of the promotion, they are some of the studies that can help to the company to improve the promotion area and sales of the company.

The speed and efficiency of the service that offers the company to solve the construction defects in the housings are perceived in an important way by the users, the design department can consider that the place of the housing where the users need more space is the room and the chambers for the development of future projects.

For the construction department it is important to mention that the recurrent defects in the housings were the cracks, the hydraulic installation and the finishes; it fits to mention that although defects are presented in the housings, people don't consider them if they are assisted with readiness to make the repairs.

REFERENCES

[1] Acero P. Sergio Alberto. The Investigation of Markets like Strategy of Competitiveness in the Construction of Housing Social of Interest., 2000 Campus Monterrey.

[2] Singh Soin Sarv"; Total Quality Control Essentials", 1992 Mc Graw Hill.

[3] García R. Salvador;. Notes of Administration of Total the Quality in the Construction., 1999 ITESM Campus Monterrey.

[4] Omachonu K. Vincent, Ross E. Joël;. "Principios de la calidad total"., 1995 Diana.

[5] Lai Kee-Hung, Weerakoon S. Thilaka;. Total Quality Management and Marketing: Complementary Business Philosophies. ,1998 International Journal of Management, Vol. 15 No.4, Pgs. 414-419

[6] Oakland S. John. " Administración por calidad total"., 1999 Cecsa.

[7] Kotler Philip, Armstrong Gary"; Principles of Marketing", 1996 Prentice Hall.

[8] Lamb W. Charles, Hair F. Joseph, McDaniel Carl;. Principles of Marketing. 1994 South Western.

[9] Spendolini J. Michael;. Benchmarking., 1994 Norma.

[10] Kinnear C. Thomas, Taylor R. James;."Investigación de marcados, un enfoque practico"., 1998 Mc Graw Hill.

[11] Malhotra K. Naresh;. "Investigación de mercados contemoranea"., 1997 Prentice Hall.

[12] McDaniel Carl, Gates Roger"; contemporary Investigation of markets", 1999 Thomson.

[13] Blankenship A.B., Breen Edward George, Dutka Alan"; State of the Art Marketing Research", 1998 NTC.
[14] Sudman Seymour, Blair Edward"; Marketing Research to Problem Solver Approach", 1998 Mc Graw Hill.
[15] Woodruff B. Robert;. Customer Valued: The Next Source for Competitive Advantage., 1997 Journal of Academy of Marketing Science, Vol. 25 No. 2, Pgs. 139-153

THE BENEFITS OF MEASURING SAFETY PERFORMANCE ON CONSTRUCTION SITES

Kunju Ahmad R
ICIOB, Faculty of Built Environment, University of Technology of Malaysia, Malaysia.

Gibb A.G.F.[2]
Department of Civil and Building Engineering, Loughborough University, UK.
A.G.Gibb@Lboro.ac.uk

Over the years, with the advancement of technology, the industry has faced many changes in the working environment including managing safety. Managing safety involves far more than merely imposing rules and policy. Successful implementation demands that safety be integrated as part of the management system itself.

The legislation has changed over the years with more emphasis on safety at work. Still today the rules and regulations are being improved to make the working environment safer. Besides the effect of laws, many safety activism factors also influence the decision of modern managers regarding health and safety such as the active role of the trade unions, consumerism and the legal battle by victims. All these factors are forcing modern managers to change their attitude towards safety. Managers are adopting proactive approaches towards safety instead of the conventional reactive ones.

This paper will discuss the benefits of measuring safety performance and the best way to go about doing it.

INTRODUCTION

The problem of safety performance has existed since the very beginning of organised attempts to control accidents and their consequences. The level of safety performance within an organisation reflects the loss that organisation will face. This loss may be due to either an accident or incident resulting in injury or property damage each time it occurs. Although the loss is not just monetary, the biggest expense is that of human life and, because safety involves human life, it is therefore important for organisations to place specific emphasis on maximising safety.

In particular, the construction industry needs to have a different outlook on safety. Safety must have equal status to other primary business priorities within construction. Young (1996) states that accident prevention forms good business practice in that a safe operation is usually an efficient one. In order to reduce the accident or incident level and therefore cut losses, it is important to ensure that safe working practice is being observed. Many factors help to activate the concern for safety such as trade unions, consumerism, technology and others. With the influence of safety activism factors, safety is becoming everyone's concern – not just the worker or individual. Safety is looking beyond accidents and more towards human behaviour and culture. Measurement will enable comparison to benchmark performance and track progress throughout a project and between organisations. Once the principle and the practice of measurement become the norm, this will transform motivations, attitudes and choices in every construction company.

REASONS TO IMPROVE SAFETY PERFORMANCE IN THE CONSTRUCTION INDUSTRY

Construction industry safety record

In the UK, the most reliable statistics are those published by the Health and Safety Executive (HSE). These statistics are used for benchmarking of safety in all industries. The HSE's annual safety statistics show that the construction industry safety performance record is worse than that of most other industries and indeed that construction has never been a champion in safety. Figure 1, 2 and 3 show the fatality record, the non-fatal injury record and over 3-day injury rate respectively for construction compared to other industries for the years 1989/90 to 1998/99 (HSE 1999).

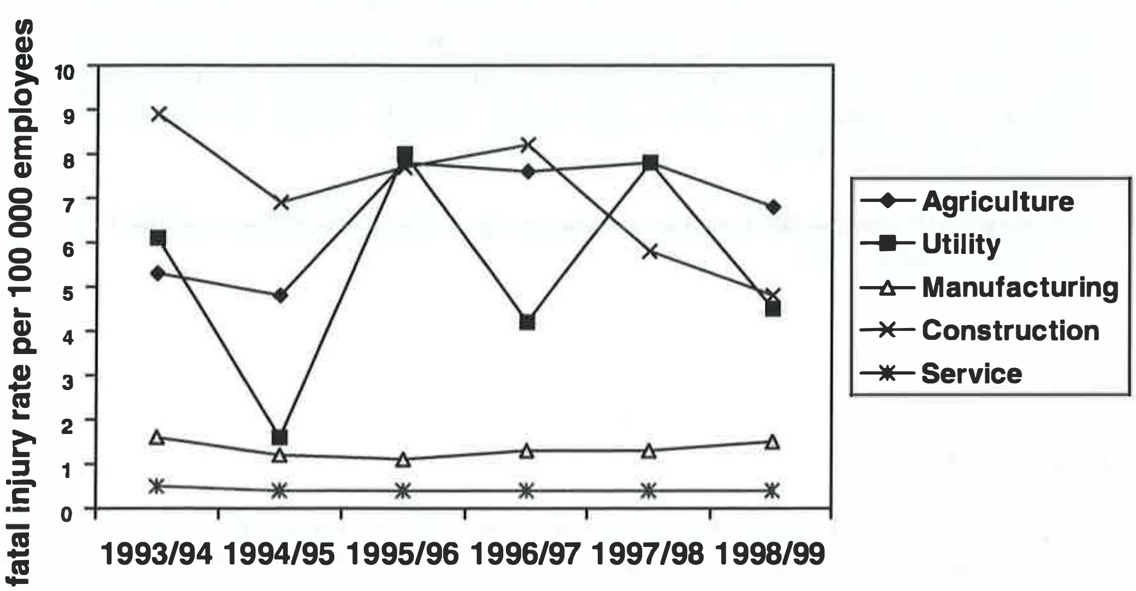


Figure 1. Fatal injury rate for employees within the industrial sector 1994/95 – 1998/99 (estimated figures)(HSE 1999)

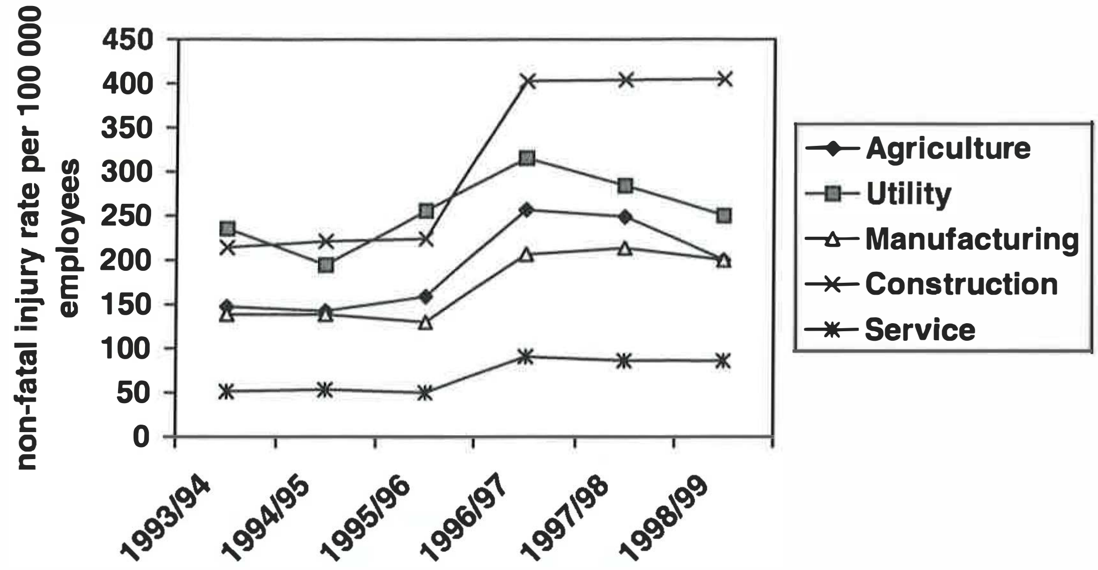


Figure 2. Non-fatal injury rate for employees within the industrial sector 1994/95 – 1998/99 (estimated figures) (HSE 1999)

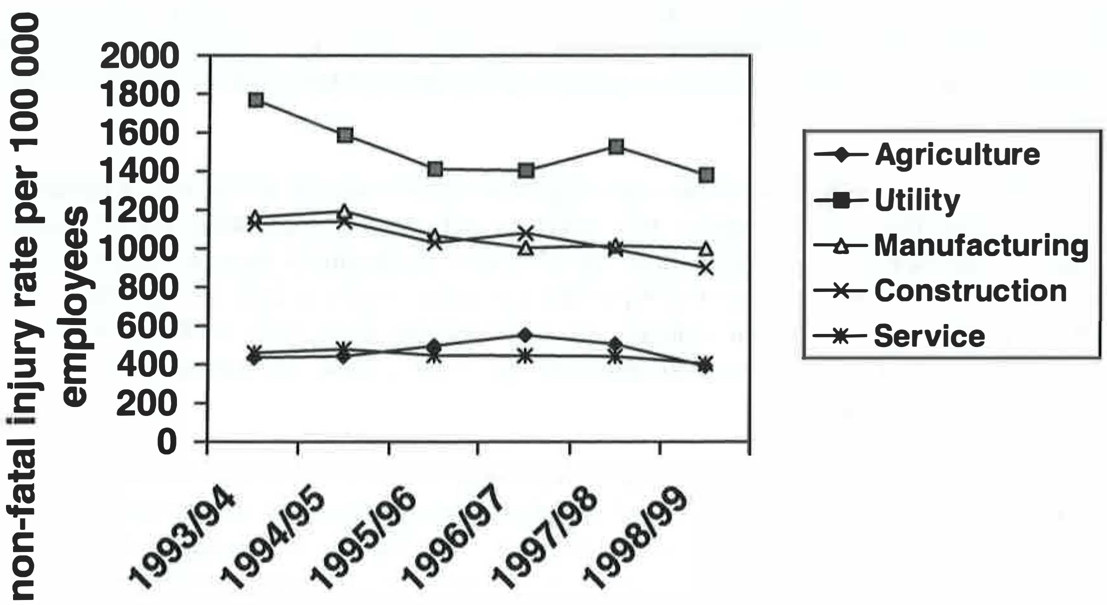


Figure 3. Over 3-day injury rate for employees within the industrial sector 1994/95 – 1998/99 (estimated figures) (HSE 1999)

The 1999 HSE annual report states that the fatal injury rate for employees within construction is expected to fall to the lowest since 1991/92 while the non-fatal major injury rate is predicted to increase by 4% to 399.2 per 100 000: - a level similar to that for 1996/97. From Figure 3, the over 3-day injury rate is seen as decreasing for the construction industry. However although the long-term trend is downward, the accident rate is still significantly above that of the manufacturing industry and other sectors. Furthermore, initial statistics for 2000-2001 show a disturbing increase in fatalities. Anderson (1998) confirms that recent extensive research into working conditions on a European scale concludes that construction and agriculture remain the sectors of employment where workers are most exposed to traditional physical risks.

Reactive data is not a reliable measure of safety

Many authors agree that the general approach to safety within the construction industry as a whole is one that is primarily 'reactive' (Jacobs (1970), Ramsey (1986), Whittington et al (1992), Lindsay (1992) and Smith et al (1996)). Smith et al (1996) and Laufer et al (1986) agree that reactive measures are post-accident measures looking at injury, ill health and incidents. The reactive measures tend to be limited to factual data about the victim such as age, gender, occupation and thus lack other vital information such as environmental conditions, task factors and behavioural factors. The report only includes activities which were directly and immediately involved in the accident and the failure to look towards understanding the factors thus limits the suitability. Even with a low reported accident rate, over a period of time, there is no guarantee that the site will be free of hazards. The authors claim that in such cases, statistics can be an unreliable and deceptive indicator of safety performance and such approaches do not evaluate project level safety performance effectively. Indeed they contribute little towards suggesting steps to prevent recurrence, and any learning from an accident becomes an expensive experience (physical and psychological damaging).

Reactive measures also rely on both the reporting of accidents and the efficiency of reporting. Historically there has always been a low level of reporting of accidents by employers. However over the period of six years since 1989/90, saw a substantial increase in these levels for most industries. Overall, the level of reporting has improved from 34% in 1989/90 to 43% in 1996/97 while for construction industry, the increase has been from 38% in 1989/90 to 55% in 1996/97 (HSE 1999). However although the figures show an increase, the level of reporting must still be improved.

Reactive measures also rely on the quality of reporting, for without proper training a report may yield poor results due to the missing of important data, difficulty in gathering data and in consistency of data. Additionally there is the problem of difference in definition of reporting. A study performed by Clarke in 1992, across twelve European countries, concluded that there are different ways of reporting accidents. For example Table 1 shows five different ways of interpreting fatal accidents, as applied across the twelve countries.

Table 1. Different definitions of fatal accidents by 12 European countries (Clarke 1992)

Fatal accident definition	Countries
Same day	Spain, Portugal
Up to 30 days	Netherlands
Up to 1 year	UK
No time limit	Denmark, Belgium, Germany, Greece, Ireland, Italy, Luxembourg

Not all countries record the date of death on the accident form. Definitions for recording accidents as fatal range from those that cause death on the same day as the accidents (Spain and Portugal) to no specified time limit. However, in Spain, the statistics may later be amended to include subsequent deaths. The shorter the length of time allowed to designate an accident as fatal, the greater the likelihood of missing some 'delayed deaths' in the fatal accident figures.

In conclusion, using reactive measures based only on measuring and comparing the frequency of accident occurrence does not seem fruitful. It is not only difficult to interpret due to the statistical 'flakiness' which governs the occurrence of rare events but also, because the expected frequency of occurrence is the product of both the risk or probability of occurrence and the magnitude or amount of human exposure.

GOOD REASONS TO IMPROVE SAFETY PERFORMANCE ON CONSTRUCTION SITES

The construction industry is becoming more aware how important it is to have an effective safety programme. There are several contributing factors including:

- responsibility;
- economic pressure;
- impact of safety on overall performance;
- contractor's performance;
- control of accident causes; and
- reporting of safety level.

Responsibility

Safety is everyone's responsibility. It is a moral and legal obligation of employers to provide a safe working place and of employees to work safely. Section 3 of the UK's Health and Safety at Work Act places obligation on employees to undertake work in a manner which will not cause risks to other persons. Ridley (1994) described the employer's duty of care to employees as covering the following areas:

- safe system of work;
- safe place of work;

- plant and machinery that is safe to use;
- competent supervision and/or suitable training; and
- care in the selection of fellow employees.

Employers too will have to provide a safe working environment and manage safety like any other company function. On a site it is also important to assign safety responsibility to all levels of management and workers.

Economic reasons

All injuries will have an adverse impact on the running of a construction project. Realising the magnitude of the problem, in 1979, the UK's Business Roundtable (BR) commissioned a series of studies to examine the costs of injuries in the construction industry. The purpose of this study as reported by BR (1982) was to draw attention to the true costs of accidents in the industry in hope for better preventive measures. The study agreed that the costs of accidents include both direct and indirect costs.

Many authors have discussed both these aspects including Hinze (1991), Everett et al (1996), Bentil (1990) and Clarke (1999). The general definition of direct costs are those that are most visible including insurable costs which can be easily quantified (this includes doctors fees, hospital fees and insurance premiums). On the other hand, the indirect costs are far more elusive to identification and particularly quantification. Hinze (1991) claimed the indirect costs (excluding claims and material damage costs) to be more than 1.67 times the direct costs of accidents.

Impact of safety performance on overall project performance

Clients and contractors have become more aware of the impact of safety performance on the overall project performance. Rodriguez (1996) showed that projects that were consistently behind schedule and over budget experienced a greater occurrence of recordable accidents. Statistically significant differences between safety performance levels were evident primarily during the middle and end of construction for projects behind schedule; projects that were over budget showed statistically significant poorer safety rates towards the end of the project.

Contractor's performance

Smith et al (1996) and Wilson et al (2000) agree that there is an adverse effect on a contractor's reputation and an unfavourable image projected onto the client when the project suffers high accident rates. It is important for a contractor to have a good image in order to enable them to tender for the next project. Wilson (2000) claimed that larger construction companies are better organised in terms of safety. It is important for large and small companies to uphold their reputation as well as maintain safety records. In order to achieve this, they must be better prepared to manage safety aspects of a project.

Control of accident causes

Laufer et al (1986) and Smith (1996) agree that safety performance measurement enables behaviours and conditions to be identified that have the greatest potential in contributing to an accident. It also forms a basis to predict future accident problems and enables management to control the causes of accidents on site. Tarrants (1980) agrees that the measurement approach essentially allows the management to establish long-term accident control. These measurement techniques provide continuous information concerning changes in the safety state within an organisation in operation. A valid and reliable measure of these changes permits evaluation of the effectiveness of accident prevention efforts over time.

Report safety level

Implementing safety performance measurement provides a description of relative levels of safety and a continuous report of fluctuations within an organisation. Smith et al (1996) agreed that the statistical data could provide a convenient mechanism for comparison and determining the relative risk of one company or one site with respect to another and form a basis for trend comparison. Safety performance measurement enables the management to order and quantify certain events and ultimately use the results as a basis for the control and prediction of actual performance. Smith continues to add that continuous reporting of safety performance is an essential prerequisite for control and prediction for future events.

IMPORTANCE OF MEASURING PERFORMANCE

The importance of measurement is reflected in Druker's statement that 'what gets measured gets done' (Hubler 1995). Measuring performance against predetermined standards can reveal when and where actions are needed to improve performance. A key question concerning measurement is whether it should be expressed in terms of behaviour, tasks, traits or organisation outcomes? Furthermore, should criteria be qualitative or quantitative? Measurements that are quantitative in nature (e.g. number of safety audits being carried out) are easy to measure when compared to the qualitative measures (e.g. measuring safety attitude of workers). Tarrants claims that, whatever measurement approach is chosen, it must be sensitive to the fundamental behaviour and conditional malfunctions that may at any time contribute to an accident loss problem.

THE WAY FORWARD - PROACTIVE APPROACH TO MEASURE SAFETY PERFORMANCE ON CONSTRUCTION SITES

Many studies and models have been developed based on this concept of unsafe behaviour and conditions including by authors such as Staley et al (1996) and Smith et al (1991). All these models agree that proactive, or pre-accident measures are the answer to producing better safety performance on site.

By having a single measurement tool, the level of safety could be determined and a benchmark towards measuring safety performance could be formed. Jacobs (1970) agrees that the benefit of having a single measurement is that it must be able to evaluate the magnitude of changes over time or in comparative evaluation of two similar situations.

The development of a single measurement tool must be able to:

- reveal safety performance level;
- measure safety effectiveness that will enable identification of accident problems;
- provide continuous information concerning change in the safety state within an organisation;
- be sensitive to the fundamental behaviour and condition malfunctions;
- define where remedial actions are required; and

- continuously generate observable improvement in the way people work and thus will definitely lead to a good safety culture.

One key limitation of existing measurement techniques is that each company will adopt or create their own measurement technique with each technique adopted being successful in its own way. Each approach adopted will only focus on specific aspects of safety in the particular organisation. The approach and methods of measurement are based on the organisation's preference and priority. The drawbacks of some of the measurements are discussed further in Kunju Ahmad (2000).

CONCLUSION

The discussion above generally encourages a more proactive approach with good management practice and the transfer of ownership of safety to every employee. Employees should recognize that the key determinant of successful management is the promotion of positive safety culture and that good safety performance is not just a matter of preparation of well-structured company safety procedures. Today, safety management has promoted a new outlook towards safety. It should no longer be treated as secondary in the business context rather it is treated as an important part of the project or industry culture. More emphasis is being put in ensuring everyone understands the importance of safety.

In order to achieve a true safety performance level, a more proactive approach is needed. The measurement tool must be able to reduce the potential for future accidents or incidents on site in addition to reporting changes, identifying contributing factors to the causes of accidents, measuring the safety culture on site and also providing remedial actions to be taken. Implementing the measuring and monitoring of safety activities is an important signal of management commitment to safety and an essential part of a positive safety culture in the construction industry.

REFERENCES

[1] Anderson J.M. 1992. Managing safety in construction. *Proceedings of the Institute Civil Eng*. pp 127-132.

[2] Anderson J.M. 1998. Addressing barriers to improve safety performance. *Construction Manager*. Nov, Vol. 4, Issue 9, pp 13-15.

[3] Bentil KK. 1990. Construction site safety: A matter of life & cost. *Cost Engineering*. Vol. 32 No 3, pp 7-11.

[4] Chhokar J.S. & Wallin J.A. 1984. Improving safety through applied behaviour analysis. *Journal of Safety Research*, Vol. 15, pp 141-151.

[5] Clarke R.C. 1992. Methodology for the Harmonisation of Euro Occupational Accident Statistic. Eurostst.

[6] Everett J.G. & Frank P.B. 1996. Cost of accident & injuries to the construction industry. *Journal Construction Management & Economic*. Vol. 122,No2, pp 158-164.

[7] Hinze J W & Applegate L.L. 1991. Cost of construction injuries. *Journal of Construction Engineering & Management*. Vol. 117, No 3, pp 537-551.

[8] HSE. 1999. *Safety Statistics Bulletin 1998/99*. UK: Health and Safety Executives

[9] C65 07/99.

[10] Hubler W G. 1995. Behaviour based approach to creating a strong safety culture. *SPE/IADC Drilling Conference*. pp 361-373.

[11] Jacobs H.H. 1970. Towards more effective safety measurement system. *Journal of Safety Research*. Vol. 2 No 3, pp 161-175.

[12] Kletz T A. 1993. Accident data-the need for a new look. *Safety Science*. Vol. 16, pp 407-415.

[13] Laufer A. 1986. Assessment of safety performance measurement at construction sites. *Journal Construction Management & Economic*. Vol. 112 No4, pp 530-542.

[14] Lindsay F.D. 1992. Successful health & safety management. The contribution of management towards safety. *Safety Science* Vol. 15, pp 387-402.

[15] Liska R W. 1993. *Zero Accident Technique*. Construction Institute Industry.

[16] Ramsey J D, Burford C.L. & Beshir M.Y. 1986. Systematic classification of unsafe worker behaviour. *International Journal of Industrial Ergonomics*. Vol. 1, pp 21-28.

[17] Ridley J. 1994. *Safety at Work*. Oxford: Butterworth-Heinmann.

[18] Rodriguez Y A & Jaselskis E.J. 1996. Relationship between project performance and accidents. *Proceeding of the 1st International Conference of CIB*. Lisbon, W99. pp 251-258.

[19] Smith G.R & Arnold T.M. 1996. Safety performance measurement for masonry construction. *Proceeding of the 1st International Conference of CIB*. Lisbon, W99. pp 103-114.

[20] Staley EI BG & Foster P.J. 1996. Investigating accidents & incidents effectively. *Mining Technology*. Vol. 78 No 895.

[21] Tarrants W E. 1980. *The Measurement of Safety Performance*. NY: Garland STPM.

[22] Whittington C, Livingston A & Lucas D.A. 1992. *Research into Management, Organisation & Human factors in the Construction Industry*. Health and Safety Executives, Report 45/1992.

[23] Wilson J.M. and Koehn E.E. 2000. Safety management: problems encountered and recommended solutions. *Journal of Construction and Engineering Management*. Vol. 126, No. 1, Jan/Feb, pp 77-79.

[24] Young G S 1996. Reengineering construction safety: A vision for the future. *Proceeding of the 1st International Conference on CIB*. Lisbon, W99. pp. 129-136.

BENCHMARKING CONSTRUCTION HEALTH AND SAFETY (H&S)

John Smallwood
Department of Construction Management, University of Port Elizabeth, South Africa.
coajjs@upe.ac.za

Benchmarking entails the comparison of a contractor's processes with those identified as best practice, internally, or competitively within the industry, or generically with all industries. Ideally, benchmarking should engender continuous improvement in H&S, and ultimately, the achievement of the goal of 'zero accidents'. However, traditionally H&S related measures and consequently 'benchmarks', have been focused at the incidents end of the upstream/downstream sequence: culture → management system → exposure → incidents. Although 'downstream' measures have their merits, they are essentially historical and do not measure 'upstream' factors which are predictors of likely 'downstream' performance. 'Upstream' benchmarks are also of particular importance to clients, project managers (PMs) and principal agents (PAs) as optimum H&S complements cost, productivity, quality, schedule and the environment.

This paper reports on two descriptive surveys, which were conducted to determine preferred general and 'upstream' H&S benchmarks. PMs were surveyed to determine the H&S benchmarks which would be useful to 'clients' of general contractors (GCs), and GCs were surveyed to determine the H&S benchmarks which would enable internal and competitive benchmarking, and assist them in continuous improvement endeavours.

Although 'downstream' measures such as the disabling injury incidence rate (DIIR) were identified as being preferred, 'upstream' measures such as: availability of a documented H&S management system, H&S policy and H&S rules; percentage activities for which safe work procedures are available, and the percentage of management, supervisors and workers educated and trained in H&S, were identified by the majority of PMs and GCs.

Keywords: Benchmarking, health and safety, measures, upstream, downstream.

LITERATURE

Introduction

There are three types of H&S benchmarking: internal; competitive (within industry), and generic (all industries) (Mc George and Palmer, 1997). Internal: ideally GCs would know how individual projects are performing relative to 'best practice' and average performance in their organisation. Competitive: GCs are able to compare their performance, 'best practice' and average, to that of the relevant sector of the construction industry. Generic: similarly GCs are able to compare their performance to that of other industries. Competitive benchmarking also enables clients, PMs and other PAs such as designers, to prequalify and periodically evaluate GCs in term of H&S.

McGeorge and Palmer (1997) define benchmarking as "A process of continuous improvement based on the comparison of an organisation's processes or products with those identified as best practice. The best practice comparison is used as a means of establishing achievable goals aimed at obtaining organisational superiority." They also cite the series of questions recommended by Camp to assist in the identification of what should be benchmarked, inter alia, "What factors are responsible for customer satisfaction?" and maintain that H&S would possibly be cited by clients as being related to their satisfaction.

According to Blewett and Shaw (1997) benchmarking is not the solution to all management ills, neither will it be the answer to all the H&S problems in any organisation. Only once an effective H&S management system is in place can benchmarking help to improve the system.

The objectives of the study are to determine:

- the H&S benchmarks which should be and are used by GCs to compare projects internally and competitively in terms of H&S, and
- the H&S benchmarks which should be and are used by clients and PMs to compare contractors in terms of H&S.

Relevance

Blewett and Shaw (1997) consulted Australian industry in general to determine the reason for participating in benchmarking H&S. The following constitute the three main reasons.

inadequate H&S is recognised as a major constraint on organisational performance;

H&S needs to be perfected before other improvements can be realised, and an improvement in H&S will improve performance in other key organisational processes.

Incidents occur Downstream

According to Krause (1993) incidents occur downstream of culture, management system and exposure (Figure 1).

Culture →	**Management → System**	**Exposure →**	**End Points**
Values	Education/ Training	Behaviour	Incidents
Purpose	Practices	Conditions	
Vision	Programme	Plant and equipment	
Goals	Site layout	Facilities	
Mission	Behavioural consequences		
Assumptions	Priorities		
	Attitude		
	Measurement system		
	Improvement model		
	Resources		

Figure 1. Incidents are downstream (adapted from Krause, 1993).

Trethewy and Gardner (2000) maintain that to date, measurement of H&S performance has been preoccupied with injuries and illness rather than measuring management of safety in the workplace ie. at the end point of the upstream/downstream sequence, namely incidents. They say that common measures have been lost-time injury frequency rates and workers' compensation statistics and maintain that such measures, in isolation, are now regarded as inadequate to provide information to help eliminate or reduce the causes of injury or illness.

Further arguments are the following (Trethewy and Gardner, 2000). Traditional outcome measures of H&S, such as injury statistics, bear little or no relationship to 'actual' H&S performance in the workplace. 'Actual' H&S performance is in fact the effectiveness of the processes of the H&S management system, rather than the outcomes thereof ie. superior performers in H&S promote the systematic reporting of accidents and incidents and the data are then used proactively to identify trends and appropriate remedial strategies. However, contractors with poor or average performance in H&S tend to foster a culture of under-reporting by reacting negatively to reports of high accidents and incident rates. Secondly, a preoccupation with outcome performance measures engenders under-reporting, and this problem tends to be exacerbated in workplaces that convolute the chain of responsibility and reporting. Thirdly, the use of traditional indicators means that accidents or near misses which have the potential to cause injury, but do not actually result in lost time, will go unnoticed. This results in valuable resources being expended on short-term 'fix-it' strategies as a reaction to accidents that have occurred rather than strategies for long-term identification and prevention of hazards. In essence, although traditional forms of H&S performance appraisal are indicators of failure in the H&S system, they provide no real measurement of actual workplace H&S performance. However, they are needed since the prevention of such outcomes is the ultimate goal of H&S interventions. A further motivation for such traditional outcome measures is that the data can be translated into monetary terms and therefore provide solid economic argument for expenditure to reduce such outcomes.

Preferred Indicators of H&S Performance

Amis and Booth (Trethewy and Gardner, 2000) cite "What gets measured usually gets done" as a reminder of the importance of measuring performance if H&S objectives are to be achieved. Research conducted in Australia indicates that process (what gets done) indicators should be used in addition to outcome indicators (Hopkins, 1994).

The two types of process indicators are: those which focus on the behaviour of employees, and those which measure management activity (Hopkins, 1994).

An example of 'behaviour of employees' indicators is the percentage of employees wearing personal protective equipment (PPE). Such indicators focus attention on the problem, which is likely to lead to H&S improvement without the need for punitive intervention.

Given that managers are ultimately responsible for H&S and are in the best position to take action relative thereto, indicators which measure the H&S related activity of management are important. Examples include, percentage of workforce which has received H&S training, and percentage of H&S audits which have been completed timeously.

Blewett and Shaw (1997) maintain that features of H&S culture and management systems that have the greatest downstream consequences must be identified and indicators developed to determine whether these are operating effectively. Gardner (Blewett and Shaw, 1997) maintain that the indicators should have the following characteristics:

- accurate and capture all elements of performance;
- provide an indication of the extent to which H&S management procedures and systems are being implemented by the general contractor (GC) and subcontractors (SCs);
- be related to the process of managing H&S rather than outcomes alone;
- be simple so that they can be understood and acted upon by everyone in the workplace, and
- entail the use of multiple measures as no one measure is likely to be sufficient.

What should be Benchmarked?

Blewett and Shaw (1997) recommend that an organisation first analyse their own H&S management process, else they will not benefit from looking at how others do it, if they do not understand their own process. Such an analysis might identify improvements immediately, without external benchmarking. They maintain benchmarking should target only the most important features – the features which have the most effect on H&S performance, and advocate the use of the upstream/downstream model postulated by Krause. The model amplifies the need to benchmark the most important aspects of culture and the management systems which arise from it. When the most important management systems for H&S have been identified, each should be analysed to: identify where the major problems in the system are; what causes the problems, and determine what needs to be discovered from benchmarking partners.

According to Trethewy and Gardner (2000) the Australian National Occupational Health and Safety Commission (NOHSC) developed indicators for five key areas for construction:

planning and design; management processes; risk management; psychosocial working environment, and monitoring. Trethewy and Gardner (2000) in turn advocate the following categories of performance indicators with respect to the management of a project by a GC: management responsibility; contracting works; training, and compliance verification. Examples of the respective indicators are: management responsibility – budget for and tracking of H&S costs; contracting works – safe work procedures; training - management, supervisors and workers, and compliance verification – monthly outcome statistics, and hazard identification during inspections.

RESEARCH

Sample Frame

Two sample frames were included in the study.

The first consisted of 25 general contractors (GCs) which had achieved placings in the BIFSA National H&S Competition and, or BIFSA 4 or 5-Star H&S gradings on one or more of their projects. 19 GCs responded, which represents a response rate of 76%.

The second consisted of 95 members of the Association of Construction Project Managers (ACPM). One questionnaire was 'returned to sender' and 17 responses were received, which constitutes a response rate of 18.1%.

Analysis of Data

Given that respondents were required to respond in terms of usefulness on a scale of 1 (very useful) to 5 (useless), and in terms of a range of frequencies, it was necessary to compute an importance index (II) with a minimum value of 0, and a maximum value of 4, to enable a comparison of and to rank various benchmarks and practices. The (II) is calculated using the formula:

$$\frac{4n_1 + 3n_2 + 2n_3 + 1n_4 + 0n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)}$$

where n_1 = Very useful (1) or Always

n_2 = Useful (2) or Often

n_3 = Neutral (3) or Sometimes

n_4 = Nearly useless (4) or Seldom

n_5 = Useless (5) or Never/Don't know

General Contractor (GC) Findings

Table 1 indicates that the IIs for the potential H&S benchmarks are above the midpoint value of 2.0, which indicates that according to GCs, all the benchmarks can be deemed to be potentially useful when comparing projects within an organisation with others internally, and with those of other contractors.

It is notable that three of the top five benchmarks (60%) are performance orientated: written H&S policy (available); written H&S rules (available); direct cost of accidents (COA); total COA, and project H&S plans (available).

It is also notable that four of the six benchmarks (66.7%) which achieved a ranking between sixth and joint tenth are performance orientated: disabling injury incidence rate (DIIR); indirect COA; cost of prevention (COP); COP as a percentage of value of construction (%); documented H&S management system/programme (available), and percentage of supervisors which have attended a H&S course. Overall, 58.3% of the preventative orientated benchmarks achieved a ranking within the top ten. Of further significance, is that the three lowest ranked potential benchmarks are all 'outcome' orientated.

Table I. Potential usefulness of potential H&S benchmarks when comparing projects within an organization with others internally, and with those of other contractors according to GCs.

Benchmark	Response (%)						II	Rank
	Very useful..............Useless					Don't know		
	1	2	3	4	5			
Written H&S policy (available)	63.2	26.3	5.3	0.0	5.3	0.0	3.42	1=
Written H&S rules (available)	63.2	26.3	5.3	0.0	5.3	0.0	3.42	1=
Direct* cost of accidents (COA) (Rand)	47.4	42.1	10.5	0.0	0.0	0.0	3.37	3
Total * COA (Rand)	57.9	26.3	10.5	0.0	5.3	0.0	3.32	4=
Project H&S plans (available)	63.2	21.1	5.3	5.3	5.3	0.0	3.32	4=
Disabling injury incidence rate (DIIR)*	52.6	26.3	15.8	5.3	0.0	0.0	3.26	6=
Indirect* COA (Rand)	47.4	31.6	21.1	0.0	0.0	0.0	3.26	6=
Cost of prevention (COP) (Rand)	42.1	42.1	15.8	0.0	0.0	0.0	3.26	6=
COP as a percentage of value of construction (%)	36.8	52.6	10.5	0.0	0.0	0.0	3.26	6=
Documented H&S management system/programme (available)	68.4	21.1	10.5	0.0	10.5	0.0	3.16	10=
Percentage of supervisors which have attended a H&S course	57.9	21.1	10.5	0.0	10.5	0.0	3.16	10=
Total COA as a percentage of value of construction (%)	36.8	42.1	15.8	5.3	0.0	0.0	3.11	12=
Percentage of management educated in H&S	52.6	31.6	0.0	5.3	10.5	0.0	3.11	12=
Frequency of H&S inspections	42.1	42.1	5.3	5.3	5.3	0.0	3.11	12=
Percentage of workers which have attended a H&S course	57.9	10.5	21.1	5.3	5.3	0.0	3.11	12=
Percentage activities for which safe work procedures are available	47.4	15.8	26.3	10.5	0.0	0.0	3.00	16
Frequency of H&S site meetings	36.8	26.3	21.1	5.3	10.5	0.0	2.74	17
Medical aid incidence rate (MAIR)*	26.3	26.3	26.3	15.8	5.3	0.0	2.53	18
Modified severity rate (SR)*	26.3	21.1	31.6	15.8	0.0	5.3	2.47	19
Fatality rate per 100 000 workers	21.1	15.8	36.8	10.5	10.5	5.3	2.16	20

* Direct cost includes the cost of medical and related care and the lost wages recoverable from the workers' compensation insurer (insured costs).

* Total COA is the sum of the direct and indirect costs.

* A disabling injury (DI) is an injury which results in the loss of a shift after the day on which the injury occurred. The DIIR represents the number of DIs per 100 workers per year.

* Indirect cost includes the uninsured costs, such as reduced productivity, penalties, re-training etc.

* The MAIR represents the number of injuries requiring medical aid per 100 workers per year.

* Modified severity rate represents the number of hours lost per worker per year.

Approximately half of the GCs responded that they benchmarked H&S/compared projects in terms of H&S on a monthly basis, and 15.8% annually. It is significant that 31.6% never did so (Table II).

73.6% of the GCs responded that they would be interested in participating in an industry H&S benchmarking project facilitated and managed by the Department of Construction Management, University of Port Elizabeth.

Table II. Frequency at which GCs benchmark H&S/compare projects in terms of H&S according to GCs.

Frequency	Response (%)
Monthly	52.6
Annually	15.8
Never	31.6
Don't know	0.0
Total	100.0

61.5% of the 68.4% of the GCs that responded that they benchmarked H&S/compared projects in terms of H&S, recorded the benchmarks. The respective benchmarks and the corresponding percentages (expressed as a percentage of the responding population) are presented in Table III.

Table III. Benchmarks used monthly or annually by GCs to benchmark/compare projects in terms of H&S.

Benchmark	Response (%)
COP	5.3
DIIR	21.1
MAIR	10.5
Plant accidents / hours operated	5.3
Site performance as a percentage of optimum	5.3
SC performance as a percentage of optimum	5.3
Total number of accidents	10.5
Vehicle accidents / km traveled	5.3

Project Manager (PM) Findings

Table 4 indicates that fourteen of the IIs for the potential H&S benchmarks are above the midpoint value of 2.0, which indicates that according to PMs, 70% of the benchmarks can be deemed to be potentially useful when prequalifying contractors and when assessing contractors' performance on projects.

It is significant that all five of the top five ranked benchmarks are performance orientated: percentage of supervisors which have attended a H&S course; written H&S policy (available); written H&S rules (available); documented H&S management system/programme (available), and percentage of workers which have attended a H&S course.

It is also significant that four of the five (80%) benchmarks which achieved a ranking between sixth and tenth are performance orientated: percentage of management educated in H&S; frequency of H&S site meetings; frequency of H&S inspections, and project H&S plans (available). It is notable that eleven of the top twelve (91.7%) ranked benchmarks are performance orientated. Of further significance, is that the six lowest ranked potential benchmarks are all 'outcome' orientated.

Table IV. Potential usefulness of potential H&S benchmarks when prequalifying contractors and when assessing contractors' performance on projects according to PMs.

Benchmark	Very useful.....Useless					Don't know	II	Rank
	1	2	3	4	5			
Percentage of supervisors which have attended a H&S course	37.4	50.0	6.3	6.3	0.0	0.0	3.19	1
Written H&S policy (available)	37.4	50.0	0.0	12.4	0.0	0.0	3.13	2
Written H&S rules (available)	37.4	43.8	6.3	12.4	0.0	0.0	3.06	3=
Documented H&S management system/programme (available)	37.4	43.8	6.3	12.4	0.0	0.0	3.06	3=
Percentage of workers which have attended a H&S course	25.0	62.5	6.3	6.3	0.0	0.0	3.06	3=
Percentage of management educated in H&S	31.3	43.8	18.8	6.3	0.0	0.0	3.00	6
Frequency of H&S site meetings	31.3	37.4	25.0	6.3	0.0	0.0	2.94	7=
Frequency of H&S inspections	31.3	37.4	25.0	6.3	0.0	0.0	2.94	7=
Disabling injury incidence rate (DIIR)	25.0	37.4	25.0	6.3	6.3	0.0	2.69	9=
Project H&S plans (available)	31.3	31.3	18.8	12.4	0.0	6.3	2.69	9=
Percentage activities for which safe work procedures are available	31.3	12.4	18.8	31.3	0.0	6.3	2.31	11
Cost of prevention (COP) (Rand)	18.8	31.3	18.8	18.8	6.3	6.3	2.25	12
Fatality rate per 100 000 workers	18.8	25.0	25.0	12.4	18.8	0.0	2.13	13=
COP as a percentage of value of construction (%)	12.4	37.4	18.8	12.4	12.4	6.3	2.13	13=
Medical aid incidence rate (MAIR)	6.3	25.0	43.8	6.3	12.4	6.3	1.94	15=
Direct cost of accidents (COP) (Rand)	18.8	18.8	25.0	12.4	12.4	12.4	1.94	15=
Modified severity rate (SR)	6.3	25.0	43.8	0.0	12.4	12.4	1.89	17
Total COA as a percentage of value of construction (%)	6.3	31.3	12.4	18.8	18.8	12.4	1.75	18
Indirect COA (Rand)	12.4	0.0	43.8	12.4	18.8	12.4	1.50	19=
Total COA (Rand)	12.4	12.4	25.0	12.4	25.0	12.4	1.50	19=

Given that the IIs for the prequalifying of contractors on H&S by clients and PMs are below the midpoint value of 2.0, such prequalifying cannot be deemed to be prevalent. However, it is notable that nearly one-third of PMs maintained that their practices 'sometimes' prequalify contractors on H&S (Table V).

Table V. Frequency at which clients and PMs prequalify contractors on H&S according to PMs.

Stakeholder	Response (%)						II
	Always	Often	Sometimes	Rarely	Never	Don't know	
Clients	12.5	0.0	6.2	31.3	50.0	0.0	0.94
Your practice	12.5	12.5	31.3	18.7	25.0	0.0	1.69

28.6% of the PMs which responded that clients prequalify contractors on H&S, recorded the following benchmarks: compliance with the OH&S Act (14.3%), and H&S policy (14.3%).

45.5% of the PMs which responded that their practices pre-qualify contractors on H&S, recorded the following benchmarks: H&S systems & procedures (9.1%); 4 – Star H&S grading (9.1%); H&S policy (18.2%); H&S manual (9.1%); documented H&S records (9.1%); participation in industry H&S initiatives (9.1%); H&S rules (9.1%); H&S programme (9.1%), and H&S inspections (9.1%).

Consolidated Findings

Table 7 indicates that all the mean IIs for the potential H&S benchmarks are above the midpoint value of 2.0. It is significant that the top five ranked potential benchmarks are performance orientated: written H&S policy (available); written H&S rules (available); percentage of supervisors which have attended a H&S course; documented H&S management system/programme (available); and percentage of workers which have attended a H&S course. It is also notable that four of the five (80%) potential benchmarks which achieved a ranking between sixth and tenth are performance orientated: percentage of management educated in H&S; frequency of H&S inspections; project H&S plans available, and frequency of H&S site meetings. Of further significance, is that the five lowest ranked potential benchmarks are all 'outcome' orientated.

Table VI. Overall potential usefulness of potential H&S benchmarks according to GCs and PMs.

Benchmark	GCs		PMs		Mean	
	II	Rank	II	Rank	II	Rank
Written H&S policy (available)	3.42	1=	3.13	2	3.28	1
Written H&S rules (available)	3.42	1=	3.06	3=	3.24	2
Percentage of supervisors which have attended a H&S course	3.16	10=	3.19	1	3.18	3
Documented H&S management system/programme (available)	3.16	10=	3.06	3=	3.11	4
Percentage of workers which have attended a H&S course	3.11	12=	3.06	3=	3.09	5
Percentage of management educated in H&S	3.11	12=	3.00	6	3.06	6
Frequency of H&S inspections	3.11	12=	2.94	7=	3.03	7
Project H&S plans (available)	3.32	4=	2.69	9=	3.00	8
Disabling injury incidence rate (DIIR)	3.26	6=	2.69	9=	2.98	9
Frequency of H&S site meetings	2.74	17	2.94	7=	2.84	10
Cost of prevention (COP) (Rand)	3.26	6=	2.25	12	2.78	11
COP as a percentage of value of construction (%)	3.26	6=	2.13	13=	2.70	12
Direct cost of accidents (CO) (Rand)	3.37	2	1.94	15=	2.66	13=
Percentage activities for which safe work procedures are available	3.00	16	2.31	11	2.66	13=
Total COA as a percentage of value of construction (%)	3.11	12=	1.75	18	2.43	15
Total COA (Rand)	3.32	4=	1.50	19=	2.41	16
Indirect COA (Rand)	3.26	6=	1.50	19=	2.38	17
Medical aid incidence rate (MAIR)	2.53	18	1.94	15=	2.24	18
Modified severity rate (SR)	2.47	19	1.89	17	2.18	19
Fatality rate per 100 000 workers	2.16	20	2.13	13=	2.15	20

Summary

Currently, H&S benchmarking is undertaken to a degree by GCs.

Currently, prequalification of contractors on H&S by PMs and clients cannot be deemed to be prevalent.

Based upon the response of GCs, all the potential H&S benchmarks can be deemed to be potentially useful when comparing projects within an organisation with others internally, and with those of other contractors.
Based upon the response of PMs, 70% of the potential H&S benchmarks can be deemed to be potentially useful when prequalifying contractors and when assessing contractors' performance on projects.

'Performance' orientated benchmarks predominate in terms of potential usefulness, 'outcome' orientated benchmarks achieving generally lower rankings.

CONCLUSIONS

International literature advocates primarily the use of performance measures as opposed to outcome measures for H&S. However, the outcome measures are necessary to motivate the need for addressing H&S. Based upon the descriptive survey, the level of H&S benchmarking and prequalifying of contractors on H&S is not satisfactory. Given that the sample frame constitutes the 'best practice'/'committed' GCs in terms of H&S, and that both the GC and PM respondents are likely to constitute the more 'committed' in the construction industry, then this conclusion is reinforced.

There is a realisation among both GCs and PMs that 'performance' orientated benchmarks are potentially more useful than 'outcome' orientated benchmarks ie. incidents/accidents are at the end of the H&S upstream/downstream sequence: culture → management system → exposure → incidents/accidents, and consequently, written H&S policy, which encapsulates the H&S culture of an organisation is an indicator of likely, and influences 'downstream' performance. This could be an indication of a paradigm shift from 'outcome' benchmarks to 'performance' benchmarks.

RECOMMENDATIONS

GCs should benchmark H&S on projects within their organisations with others internally on a monthly basis, and ideally, with those of other contractors on a monthly basis, the emphasis being on 'performance' benchmarks.

Clients, PMs and principal agents should prequalify contractors on, and assess contractors' performance using H&S benchmarks, the emphasis being on 'performance' benchmarks.

REFERENCES

[1] Trethewy R. and Gardner D. 2000. OHS performance: improved indicators for contractors. The Journal of Occupational Health and Safety Australia and New Zealand, 16 (6), 527-534.

[2] Hopkins A. 1994. The limits of lost time injury frequency rates. In Positive Performance Indicators Beyond Lost Time Injuries Part 1 – Issues (Worksafe Australia, ed). Worksafe Australia, Canberra.

[3] Blewett V. and Palmer A. 1997. Construction Management new directions. Blackwell Science, Oxford.

[4] Krause T.R. 1993. Safety and Quality: Two Sides of the Same Coin. Occupational Hazards, April, 47-50.

COSTS AND BENEFITS RELATED TO QUALITY AND SAFETY AND HEALTH IN CONSTRUCTION

MONDAY, 22 OCTOBER 2001

TOPIC: MANAGEMENT OF CONSTRUCTION QUALITY AND SAFETY AND HEALTH COSTS.

THE COSTS OF DETECTING HUMAN ERRORS IN BUILDING PROJECTS

Per-Erik Josephson, Bengt Larsson
Dept. of Building Economics and Management, Chalmers University of Technology, Sweden

Peter Love
School of Architecture and Building, Deakin University, Australia
per-erik.josephson@bem.chalmers.se

The causes of human error in building projects are very complicated and can be expensive. To reduce the consequences of human errors in construction they need to be detected as early as possible in the procurement process. With this in mind, this paper discusses the costs associated with detecting errors during the formative stages of a building project. Based on an analysis of the 10% most expensive errors from seven building projects, which represented 66% of the total error cost, it is suggested that the cost of errors can be reduced by 62% through their earlier detection. The largest cost reduction can be made for errors in material deliveries and in external walls. The paper recommends that managers should make sure that every single project member understands that error detection, indication and reporting, and at the same time reduce the administration burden of employees, should form part of daily tasks.

Keywords: Cost, defect, error detection, human error, cost reduction.

INTRODUCTION

“Painful error in the tunnel project” was a headline in the Swedish newspaper ”Göteborgs-Posten” the 14th of November 2000. In the article we could read the following text.

> ”A data input error in the computer resulted in that one section of the Chalmers tunnel is not following the original profile, but goes too high up. The deviation is up to two and a half meters”....”. The error occurred when our personnel would transfer the municipalities’ technical data into the Norwegian program for production data. It has to do with the human factor, says the manager' for the tunnel contractor’. The funny thing is that it has not been detected earlier, neither by us nor the client.” (Authors translation)

In February 2001, another Swedish newspaper - "Dagens Nyheter" - in a series of articles paid attention to mould problems in new apartments in Hammarby Sjöstad, Stockholm. In this article the journalist Per Luthander wrote:

> "'The company's representatives do not have any proper answer. - We had large roofs to cover with pasteboard and tarpaulins. Nobody had calculated that it would pour with rain three weeks without stopping. What it rained! Well, I never. It is never possible to cover to one-hundred-per-cent and we had no luck during the critical part of production, says 'the site manager'. - We simply covered too bad, it is so simple, declares 'the company's environmental manager'. The rain came down in torrents and diffused in the building timber, principally in walls but also in windows. The moisture sticked to, but was not detected until some time in November or December when the contractor put the heat on indoors. Then the mould appeared". (Authors translation)

Both incidents were painful, especially for the contractors but also for the clients. In both the tunnel project and in Hammarby Sjöstad, the consequences of not detecting the errors was costly as they had to be rectified, they caused delays and created bad-will

In both cases there were comments about how surprised the managers were that the errors were not detected earlier. What is interesting is that similar comments can be found in most discussions on major failures and catastrophes in the building industry. Thus, there is a need to learn how human errors can be detected earlier to reduce costs. With this in mind, this paper determines the costs associated with late detection of human errors in building projects. Furthermore, the paper demonstrates how much the cost of errors can be reduced through their early detection and where in the procurement process errors should be detected.

Fundamentally, many errors can be detected early using a number of techniques, such as quality assurance and quality costing. A dilemma, however, is that most suggested improvements involve new activities, increased administration and therefore may lead to perceived increased costs as the costs of error are reduced.

HUMAN ERRORS, DEFECTS AND COSTS

Errors can be regarded as chains of events, including causes (on individual, organisational and global level), human error, defect, consequences and corrective measures. Every such chain of events may include several causes and consequences, but not more than one single *primary* human error and one single *primary* defect. If neither the primary error nor the primary defect is detected, further actions will be based on it. These following actions we here call *secondary* human error etc.

Almost all human errors are closely related to a defect. Here, "defect" is defined as deviations from what is intended, caused by human actions. Changes due to changed customer needs are not considered as defects. Defect refers to both deviations in products and interruptions in processes. Thus, human error results from human actions leading to a defect.

Error costs include actual costs for corrective measures and other measurable losses. Any future costs that may arise are not included. Costs for delays are only included if it can be traced back to a specific defect. The study is limited to errors detected on building sites during the production process.

There are many studies on error costs, defect costs, failure costs, rework, deviation costs, poor quality costs etc. These are often compared without considering scope, definitions and methods used. Of that reason most papers in this field is a bit confusing.

Poor quality costs have been identified to range from 10 to 30 % of a company's turnover (Harrington, 1987, Gryna, 1988, Sörqvist, 1998). Similar figures have been reported for building and civil engineering projects. This may be true if we use a wide definition of poor quality and include all losses associated with imperfect products and processes. Differences in measurement and definitions of poor quality have resulted in a range of costs being reported in the literature (Gluch and Josephson, 1999). Poor quality costs in construction have been found to range from 0 to 12 % of a project's contract value (Burati *et al.*, 1992, Josephson and Hammarlund, 1999, Nylén, 1999, Love *et al.*, 1999).

ERROR DETECTION

Detection of human errors is seldom studied within the construction industry. It is more common in computer science and research in industries with more hazardous business, such as nuclear power and aviation. Klein *et al.* (1997) studied possibilities for humans to detect errors in data. They conclude that system-based error detection is not enough. Human-based error detection must be integrated. They argue that humans can and do detect errors under certain circumstances, and that human error detection performance can be improved.

Signal detection theory, for example, suggests that two key factors drive the performance of individuals attempting to distinguish between signal and noise: the discriminability of the distributions and the response criterion (Klein *et al.*, 1997). In construction, the discriminability may vary dependent on stress level and on how many tasks are being undertaken at a particular point in time on-site. The response criterion probably varies between individuals and may depend on stress level, knowledge and experience. Based on experiments Klein *et al.* (1997) found that incentives for detecting errors and explicit goals had an impact on discriminability and the response criterion.

Sasou and Reason (1999) studied events occurring in nuclear power, aviation and shipping industries. They describe that the error-recovery process may fall into any of three stages: *detection*, *indication* and *correction*. The first step in recovering errors is to detect their occurrence. Once detected, the recovery of an error will depend upon whether it is brought to attention to the person who is responsible for correction. An error that is detected but not indicated will not necessarily be recovered and the actions based on those errors are likely to be executed. The last step is the actual correction of errors. If the error is not corrected, the actions based on those errors will go unchecked.

In a study of almost 3000 human errors (Josephson and Hammarlund, 1996), which were found and indicated on construction sites, 72% of the errors were judged to could have been detected earlier. 37% of the errors could relatively easy have been detected earlier. Another 35% of all errors were possible to be detected earlier. Design errors and errors associated to installations were judged to be easiest to detect earlier. Josephson and Larsson (2001) identified the following reasons for late error detection:

- a lack of information about the project and the end product may cause a lack of understanding of how a specific task fits into the total project.
- a lack of incentives for detecting and indicating errors.

- a lack of resources. All project members complain about the time available to co-ordinate, plan and inspect the work. There is not even time for reflection.

Josephson and Hammarlund (1996) concluded that errors are quite often detected but not indicated. Reasons for this include, errors are of a minor nature, forgetfulness, lack of knowledge and experience or that simply because people do not want to interfere in the process. Only 79% of indicated errors were fully recovered. 4% of all errors indicated were not corrected at all, in most cases after clients decisions. The most common reason was that it was too expensive to correct these errors, especially design errors and errors associated with installing equipment. The number of errors not corrected is supported by Josephsons (1994) study of 1460 errors from one building project. In this study 80% of the errors fully corrected and 8% were left without any correction at all (Josephson, 1994). NEDO (1987) found that 20% of 500 quality-related events were not corrected.

METHOD

This paper is based on an analysis of data from seven medium-sized building projects, which were monitored during a 4 – 6 month period between 1994-96. Seven observers were educated in error collection and causes analysis and then placed at one site each with the single task of documenting errors. By making site rounds, the observers were in daily contact with all personnel. When necessary, they communicated with clients, designers, material manufacturers and other external sources of project information. Observers took part in meetings and read project documentation. In total were 2,879 human errors registered and described with codes and free text. Drawings, sketches and other relevant documents were attached to single error descriptions. Across projects, the correction cost percentage varied between 2.3 and 9.4% of the cost of production for the seven projects during the observation period. The error cost seems to be underestimated in many cases. One example is that the observers estimated that roughly 60-90% of all human errors were detected and indicated. Another example is that when showing practitioners, designers as well as construction managers and labour, errors and telling the cost to correct them, they often comment on how low the costs are. That indicates that early detection may have greater influence on the cost than what will be shown here.

Errors and their associated costs follow the well-known *Pareto* principle, which means that a few errors cause most of the error cost. For this reason, the 10% most expensive errors, representing 66% of the total error cost, were chosen for a special analysis of error detection. Of these 288 errors, 42 were excluded because they were not fully described, were unsuitable for analysis (accidents and thefts) or they included several minor errors found during special inspections. Four experts – one architect, one structural designer and two contractors – were invited for this analysis in 2000/2001. All of these professionals had 15 to30 years of work experience in their field of expertise. Two of them were involved in the initial study. After an initial group discussion on three errors of different types, they individually analysed 50 to120 errors each, according to their field of expertise. To test reliability and validity, 30 errors were given to at least two experts. For each error, four questions were asked: When should the error have been detected? Who should have detected the error? What was needed to detect the error? What would the error cost have been if the error had been detected at this time?

AN EXAMPLE: THE WINDOW, WHICH BECAME TOO WIDE

A large opening for window on the third floor in a school building was found to be 1.5 meter too wide (Figure 1). The error lead to that the external wall with facing bricks and wooden panelling became shorter than designed and as a result the electric wires were wrong assembled.

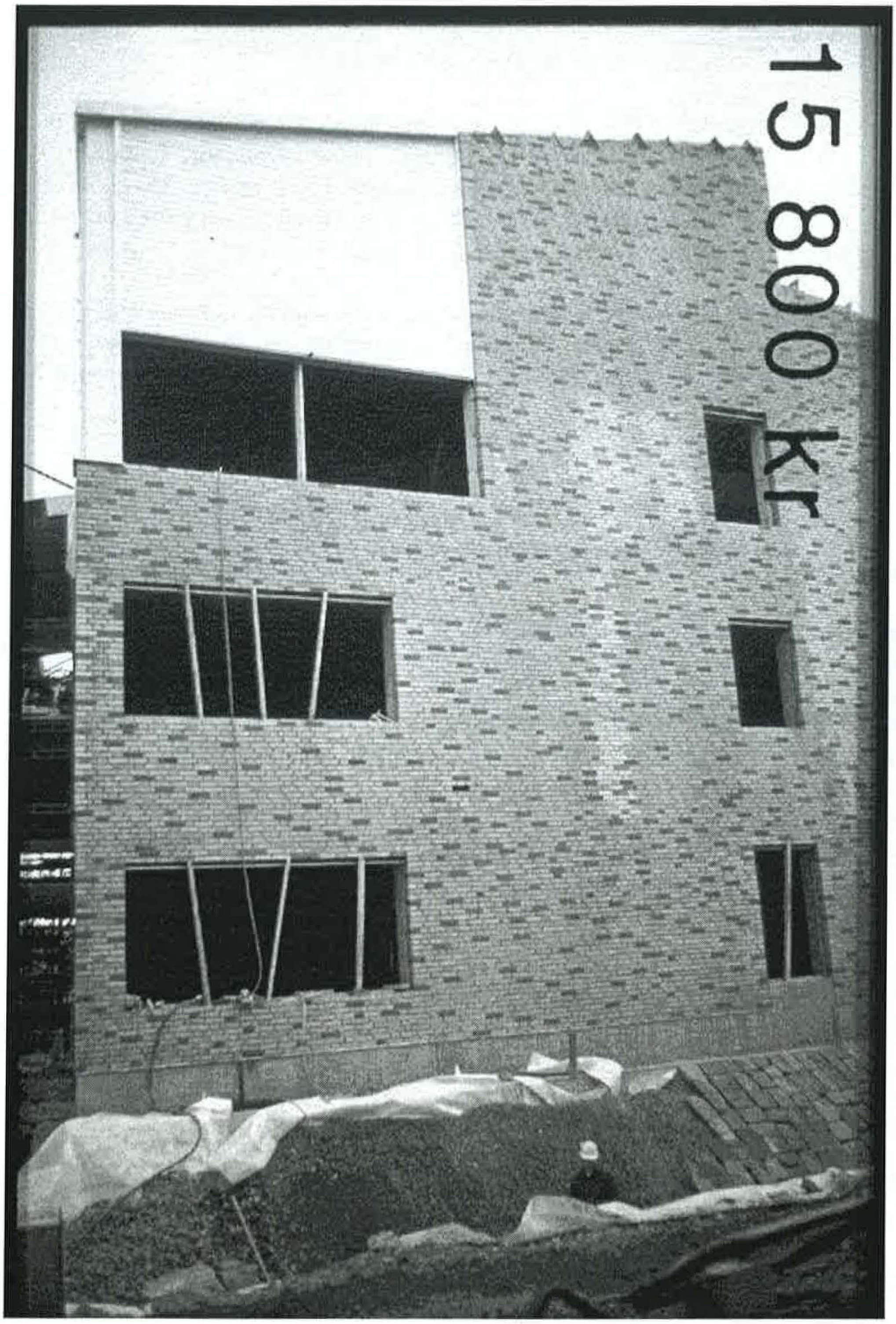


Figure 1. The upper opening for window became too wide.

A foreman had marked the outer measurement for the opening on a sill at floor level inside the building. The error chain began when a carpenter forgot to transfer the mark to a beam just below the opening. The error was detected too late to find the root-causes.
The reason for the late detection was found to be lack of incentives for detecting and indicating errors. The construction workers had already finished the window opening and the scaffolders had dismantled the scaffolding. The corrective measures became even more complicated because the workers had already moved a brook close to the front of the building. That made it more difficult to set up the scaffolding again.

The error cost became US$1580. Table I illustrates how the error cost increases the longer it takes to detection. The cost curve in this instance is an exponential function. Beside the involvement of foreman, site manager, project manager, client representative and designer in analysing the situation and solving the problem, five different categories of workers were involved in the corrective measures.

Two of the experts - the architect and one of the contractors - independently analysed this error. Both suggested that the site manager, the carpenter and the bricklayer independently should have been able to detect the error. In each case the error cost would have been negligible.

Table I. Chain of human actions following a human error before detection.

Human actions	*Accumulated costs for correction (US$)*
- The site manager does a correct setting out	-
1 The carpenter forget to transfer the mark	0
2 The carpenter build the wall	80
3 The bricklayer build external wall of bricks	150
4 The carpenter assembles external wooden panelling	200
5 The electrician assembles electric wires	250
6 The scaffolder dismantle scaffolds	800
7 Ground workers move the running of a brook	1580
- A carpenter detect the error and report it to a foreman	

POSSIBLE COST REDUCTION

Most error chains are broken after their primary human error or primary defect. Thus, most error chains have low costs for correction. This study is focused on the most expensive error chains. Most of these have high correction costs as they are detected late. Most of these chains consist of up to ten human actions after the primary error.

In reality, it is of course not possible to detect all primary human errors and their associated defects. Some error chains are more probable to detect after the secondary or thirdly human error. In the analysis the experts have judged at which stage every error chain were most probable to break. Based on the judgements of the experts, we suggest that to the costs of errors can be reduced by 62% with better systems for error detection. With optimal error detection, the cost for the 51% most expensive errors would have been reduced by 80% or more and the cost for the 72% most expensive errors would have been reduced by 50% or more.

Origins of human errors

Largest cost reduction was judged to be in material, 74%, Table II. Many of these errors were judged to be possible to detect by the supplier before delivery. It also adds a lot of costs when material has to be either scraped or returned to the supplier for correction. The cost for sub-contractor errors were judged to be reduced by 70%. Almost half of these errors were judged to be relatively easy to detect earlier. Workmanship errors can be reduced by 69%. Most of these could have been reduced to almost no cost at all. Contractors production management errors and design errors could be reduced by 65%. Especially design errors, 92% of them, were judged to be possible to detect earlier. However, there were relatively low costs for returning drawings to designers or for designers to visit the site. In contrast to the material, most drawings were produced in town. Client errors and machine errors were more difficult to detect earlier. Client errors of which only 58% were possible to detect earlier, were often hidden until late in the process. Machine errors, of which only 49% were possible to detect earlier, were hidden in the machine.

Table II. Possible cost reduction by early error detection, by origin.

Errors origin	Possible cost reduction (% of error cost)
Material deliveries	74
Sub-contractors (management + workmanship)	70
Workmanship	69
Production management	65
Design	65
Clients	53
Mixed origins	52
Machines	12
All origins	**62**

Elements of building

Elements of the building with largest possible cost reduction were external walls, installations and structure framework, Table III. For each element the error cost could be reduced by almost 70% of its total error cost. Errors in installations were judged to be easiest to detect earlier, 45% of the errors were possible to detect earlier relatively easy. Errors in external walls and structure framework were also judged to be possible to detect earlier in great extent. Errors in roofs and earthworks were most difficult to detect earlier, which explains lower possible cost reduction.

Table III. Possible cost reduction by early error detection, by element of building.

Element of building	Possible cost reduction (% of error cost)
External walls	69
Installations	69
Structure framework	68
Structure completion	63
Interior coverings, cladding and lining, fittings	62
Roofs	42
Substructure	42
Earthworks	33
All elements	**62**

DISCUSSION

In the two introductory cases - the Chalmers tunnel and the Hammarby Sjöstad - and in the case of the window example, it is surprising that no project member was able to detect the errors earlier. In each case, an inspection would have been enough to detect the error and eliminate the error cost.

A classic discussion is how much we can invest in improvements without increase the total cost. The experts meant that reducing the error cost with 62% require a number of activities and also a bit of luck. In some cases they argued that the investments needed to detect the specific error earlier would cost more than the benefit of it. One of the designers explained that

"the question is how large resources you should spend on inspection and co-operation during the design phase. The number of errors and the error cost should of course be reduced. But somewhere there is a limit for how large costs you spend on inspections. Some of the errors had probably not been significantly cheaper if you had detected them earlier. Sometimes you deliberately choose to take a chance with some parameters. Better design in this respect gives a more secure process but not necessary a lower cost".

This situation is of course applicable on all actors in building projects.

The discussion indicates that the investments should be focused on carefully selected activities. Another argument for investing in activities aimed at error detection is that it creates several more positive effects. Many errors are not detected until the use of the building. Thus, inspection during design may uncover not only obvious errors but also errors that otherwise would remain hidden until the use phase. Most investments in improvement activities create effects, which normally not are calculated but should be considered. See further discussions on indirect costs associated with rework (Love *et al.*, 2001) and non-traditional poor quality costs, such as hidden poor quality costs, lost income, customer's costs and socio-economic costs (Sörqvist, 1998).

There are two dilemmas for improvement: The first dilemma is that most improvements end up in increased administration. In discussions with practitioners about improvement it is almost solely about adding new activities, adding new functions or roles, adding new education or training, which in turn increases administration. In this particular study, the four experts identified in total 587 situations where the errors should have been detected. In every single situation the experts suggested improvements which direct or indirect result in increased administration; developing individual characteristics, improving specific activities, establishing routines and providing resources (Josephson and Larsson, 2001). Our experience is that practitioners as well as researchers seldom recommend firms or projects to remove activities and make processes simpler in order to reduce the number of errors.

The second dilemma is the classic dilemma of improvements in building projects. We can never find a situation in which we are able to build two identical buildings with identical organisations and identical environments. For this reason we cannot change one aspect and be really sure if it will result in an improvement or not. Furthermore, if we believe that we have succeeded to improve, we cannot be really sure what influence our specific change had.

CONCLUSION

The most expensive errors in building projects often have several and complicated causes. One principal strategy to reduce error cost is to eliminate the causes. An alternative strategy to reduce error cost is to focus on early error detection. This paper discusses costs associated with late detection of human errors. It is based on an analysis of the 10% most expensive errors among 2,879 human errors from seven building projects. The analysis was made by four experts: two designers and two contractors.

One conclusion is that the error cost could be reduced by 62% by earlier detection. Largest cost reduction in percentage can be made (a) considering the origin, for errors in material deliveries, in sub-contracting and in workmanship and (b) considering element of building, for errors in external walls, installations and structure framework.

Our study indicates that several project members, independently of each other, should have detected the same error. We recommend that managers make sure that every project member understand that detecting, indicating and reporting errors are integrated in every task.

Noteworthy, all suggestions for earlier detection made by the experts in this study results increased administration. We recommend managers to strive for improvements, which (a) results in decreased administration and (b) makes it simpler to detect human errors.

ACKNOWLEDGEMENTS

The authors would like to thank all people and companies involved in the original study and we are particular grateful to the four practitioners involved in this current study. The authors would also like to thank The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning and The Development Fund of the Swedish Construction Industry for financing this study.

REFERENCES

[1] Burati, J.L., Farrington, J.J. and Ledbetter, W.B. (1992) Causes of Quality Deviations in Design and Construction. *Journal of Construction Engineering and Management*, 118 (1), pp. 34-49.

[2] Gluch, P. and Josephson, P.-E. (1999) Evaluation of methods for studying environmental errors in building and civil engineering projects. *In Proc. Nordic Seminar on Construction Economics and Organization, 12-13 April 1999*, Gothenburg, Sweden, pp. 137-144. Göteborg: Chalmers University of Technology.

[3] Gryna, F. (1988) Quality costs, In Juran, J.M., and Gryna, F., *Juran's Quality Control Handbook, 4th ed.*, McGraw-Hill, New York.

[4] Harrington, H. J. 1987. *Poor-Quality Cost.* American Society for Quality Control. Marcel Dekker, Inc. New York.

[5] Josephson, P.-E. 1994. *Causes of defects in building: a study of causes and consequences of defects and impediments of learning in building projects* (In Swedish). Report 40. Department of Building Economics and Construction Management, Chalmers University of Technology, Gothenburg, Sweden.

[6] Josephson, P.-E. and Hammarlund, Y. 1999. The causes and costs of defects in construction: a study of seven building projects. *Automation in Construction*, 8 (6), pp. 681-687.

[7] Josephson, P.-E., and Larsson, B. (2001) How to detect human errors earlier in building projects: skills, activities, routines and resources, *In Proc. of the 2nd Nordic Conference on Construction Economics and Organization, 24-25 April 2001, Gothenburg*, Sweden, pp. 211-218. Göteborg: Chalmers University of Technology.

[8] Klein, B., Goodhue, D., and Davis, G. (1997) Can humans detect errors in data? Impact of base rates, incentives, and goals, *MIS Quarterly*, June97, Vol. 21 Issue 2, pp. 169-195.

[9] Love, P.E.D., Mandal, P., and Li, H. 1999. Determining the causal structure of rework influences in construction. *Construction Management and Economics*, 17 (4), pp. 505-517.

[10] Love, P., Josephson, P.-E., and Haupt, T. (2001) Determining the indirect costs associated with rework in a building construction project, *In Proc. of International Conference on Costs and Benefits Related to Quality and safety and Health in Construction, 22-23 October 2001, Barcelona*, Spain.

[11] NEDO (National Economic Development Office) (1987) *Achieving Quality on Building Sites*, Building Economic Development Committee, London.

[12] Nylén, K.-O. (1999) *Civil Works – Unique projects or a repeatable process?* The Royal Institute of Technology, Construction Management and Economics, Stockholm.

[13] Sasou, K. and Reason, J. 1999. "Team errors: definitions and taxonomy". Reliability Engineering and System Safety, 65 (1999), pp 1-9.

[14] Sörqvist, L. (1998) *Poor Quality Costing*, Doctoral thesis No. 23, The Royal Institute of Technology, Dept of Materials Processing Production Engineering, Stockholm.

LOWER COSTS WITH BETTER CLIENTS

Ib Steen Olsen
Danish Ministry of Housing and Urban Affairs, Copenhagen (Denmark)
iso@bm.dk

In the Danish building industry, the client's costs in connection with building damage in the last few years up to 1999 have stood at around 1 per cent of construction costs. The evaluations have been carried out in connection with so-called five-year inspections of building projects built up to 1994.
There are big variations between different types of housing. Studies show that the organisation of the client's work plays a crucial role.
The aim has been 50% reduction in building damage. And five-year inspections in 2000 show that the estimated costs have now fallen to 0.6%, published in May 2001.
The main reason for this fall is believed to be the more active role played by the client.
Action has been taken on several fronts. One of the most important of these is the client's organisation of a building project. Here, the action is focused on the following four areas:

- better registration and documentation of the users' wishes and needs must be ensured, and the relationship between quality and economy must be established early on in the project;
- better use must be made of experience already gained concerning building damage through declarations by the engineers and architects that account has been taken of potential risks;
- the client must be the connecting link between the design phase, when the quality assurance must be documented, and the construction phase;
- the supervision work and the evaluation of the completed project must be better organised.

In addition, models are being developed for benchmarking both clients and local authorities, and clients will have a greater possibility of choosing companies with good references instead of just basing the choice on price.
Construction companies do not have exact figures for their costs for building damage. Large contractors have advised that around 2 per cent of turnover goes on remedying defects and building damage. It has been possible for some contractors to reduce that figure to about 0.5 per cent through intensive information and supplementary training concentrated on the structures with the highest occurrence of building damage, such as roof structures and wet rooms.
The paper will discuss the four areas in which action has been taken to improve the client's side of the work on building projects.

Key words: quality assurance, Denmark, costs, client

In Denmark, frames were created in 1986 for quality assurance of state and government-subsidised building because of many cases of building damage at the beginning of the 1980s in buildings from the 1960s.

At the same time, a building damage fund – Byggeskadefonden – was set up for government-subsidised housing. The fund has two main tasks.

Firstly, it must carry out an inspection of a building five years after the building goes into use to determine whether there is any damage or signs of damage.

Secondly, the fund must act as a kind of insurance company, ensuring that any damage discovered is repaired. If damage is found within the first five years, the fund must, if possible, claim damages from the firms that participated in the building project.

The fund carried out its first five-year inspection in 1991. In that connection a system was established for such inspections. Damage requiring repair work after the inspection was recorded as serious damage.

Five-year inspections enable close monitoring of the development of damage and make it possible to take different forms of action to reduce the extent of the damage. Considerable improvements in both organisation and building technology have already been ascertained.
In particular, action has been taken to strengthen the role of the client in the building process and thus define the requirements concerning the contractor's quality assurance. An account follows of the specific steps that have helped to bring down the cost of repairing damage.

LESS DAMAGE AND BETTER ECONOMY

The Building Damage Fund's five-year inspections up to 1999, which covered buildings from 1991 to 1994, showed that the estimated cost of repairing serious damage (in connection with the inspections) averaged slightly more than 1% of the construction cost of the buildings. It has only proved possible to hold the firms involved in the projects liable for a relatively limited percentage of the cost of repair – around 20%.

The latest five-year inspections, carried out in 2000 on buildings that went into use in 1995, show a marked improvement. The estimated cost has now been reduced to about 0.6% of the construction cost.

In money terms, the reduction is from around USD 6 million to around USD 3 million. The amount of building varies slightly from year to year.

Figures are not available for the cost of quality assurance, but it is estimated to be the same each year.

It can also be mentioned that one large contractor have advised that they have reduced their costs for repair of building damage from around 2% of turnover to around 0.5%. That has been achieved through information to the employees, supplementary training and focusing quality assurance on areas with the biggest risk of building damage.

There is no information on the cost of these activities.

Judged on this basis, it seems possible to reduce the total cost of repairing building damage to about 1% of the construction cost, as a provisional minimum, if clients and contractors make a concerted effort.

The client's action comes within four areas: interaction with the users and programming; better use of experience and a requirement concerning close scrutiny of risky solutions; "bridge-building" between designers and contractors; and organisation of supervision work and evaluation of the completed building project.

THE CLIENT MUST DEFINE AND ASSESS THE BUILDING NEEDS

The client holds a central position when the building needs are to be defined. Efficient cooperation must be established with the users, and the users' needs must be translated into a building programme. A financial analysis must be carried out of requirements and needs to ensure that the needs match the possibility of meeting them.

The client must map and define the users' expectations concerning the coming building project in cooperation with the users – in other words, their values.

In some cases, deficient dialogue has made it necessary to alter buildings a few years after they have gone into use in order to meet the users' needs. Therefore, in Denmark, a project called "Clients create values" has been initiated with the aim of providing advice on how to achieve better cooperation.

The work can be organised in different ways. One way is to establish user groups to discuss requirements and wishes concerning the coming building. The discussions can concern the architecture, function, quality level, economy and operation.

This work must include budgets showing the financial consequences of the various alternatives for both construction costs and life-cycle costs.

The environmental consequences must also be assessed.

It may also be necessary to get the risks of different solutions assessed – for example, in the case of new designs with which there is no experience. It is particularly the risk of later building damage that must be assessed.

DECLARATIONS CREATE BETTER SOLUTIONS

It is important to make good use of experience. In Denmark, firms responsible for the design of building projects must show, through so-called declarations concerning risk-encumbered aspects, that they have used existing experience. The client must demand documentation from the designers.

It has been found that some building damage is due to the fact that existing knowledge has not been used. In the daily work it is not an easy matter to get concrete experience out to the building site and used.

In many cases, the damage is already born on the drawing board, simply because the designers have not used available experience – of their own or others. In Denmark, it has therefore been decided that the designers of government-subsidised housing must provide so-called declarations on risk-encumbered aspects of their projects.

In such a declaration, the designers guarantee that the chosen solutions do not imply a risk of building damage. Here, a risk is defined as the probability of damage occurring, multiplied by the financial consequences. In other words, a low probability and few consequences give a low risk. Conversely, a high probability and major consequences give a high risk.

The use of such declarations underlines the importance of using already available experience. As an aid, a database containing documented experience on damage has been established. The database is publicly accessible via the Internet.

It has also been decided that life-cycle assessments shall be made of future building projects. In practice, this means calculating both the construction costs and the later operating costs. The result will be either a total life-cycle cost at the time of the construction of the building project or an annual cost within a specific span of years.

These assessments will force the designers to assess the cost of different solutions and thus include the client's experience from other building projects. It has been found that this creates a positive and forward-looking dialogue on the design of building projects.

Lastly, it can be mentioned that new forms of cooperation have been used in a number of building projects. What happens in practice is that the client, after choosing a group of companies on the basis of a competition, sits down with the companies and participates in the design of the building project.

In this way, the expectations are matched to the project. The client has a better idea of what he can get, and the contractor has a better idea of what he is to do.

A development project has indicated 10 ways of improving the cooperation.

THE CLIENT BUILDS BRIDGES BETWEEN THE DESIGNERS AND THE CONTRACTORS

The client plays a central role when project information, in the form of drawings and specifications, is to be passed on to the contractor. It is important for the client to organise and monitor the interaction between the designers and the contractors.

The first frame for quality assurance in the Danish building sector included a meeting between the contractor and the designers to discuss the coming construction work at the building site. The experience with this procedure has been good.

This frame has now been changed, making it the client who takes the initiative for the meeting and conducts it. This helps to impress on the contractor and the designers the importance attached by the client to the exchange of information.

In practice, this meeting gives the contractor the opportunity of commenting on the proposed solutions and of suggesting others if he finds that appropriate from the point of view of possible building damage and later operation.

Such a meeting has the following agenda: presentation of the client's and the contractor's organisation during the performance of the contract; a briefing by the contractor on his plans for the construction work; any comments the contractor may have on the project material; a discussion; and any proposals for changes.

It is important here to maintain the parties' respective responsibilities, which are not intended to change. However, the meeting provides the contractor with the opportunity of commenting on the project material and of improving the actual construction at an early point of time.

Lastly, the client requires detailed project material before commencement of the work at the building site. This avoids misunderstandings during the performance of the work. A system has been developed for specifications that includes uniform specification items that can be reused.

THE CLIENT MONITORS AND EVALUATES THE PROJECT

The client must ensure effective supervision of the performance of the contract and play an active role in the handing-over of the project. The client must subsequently carry out both a technical inspection and a broader evaluation of the completed project.

It is the contractor's task to carry out the project at the building site in accordance with the project material and agreements. However, it has been found useful for the client to monitor the contractor's work through site supervision.

In practice, the client states what documentation the contractor must supply for his quality assurance and, through his site supervision, monitors structures and installations to which the client attaches high priority.

The client must also ensure that the handing-over procedure is both effective and systematic. Through his supervision, the client can already plan the later handing-over of the project and prompt action to remedy defects and deficiencies during the final phases of the project. The actual handing-over procedure must proceed systematically so that all the work performed is carefully inspected.

Later, the client must arrange for technical inspections. In Denmark, inspections have been introduced one year and five years after a building has gone into use. In addition, a system is now being established for broader evaluation of completed building projects, covering – for example, the architecture, lifetime costs, environmental aspects and the users' experiences.

As a pilot project, around 1,000 homes in 17 housing projects are being evaluated on the basis of the following parameters: building technology, architecture, indoor climate (including acoustics), environmental impacts, lifetime costs and resident satisfaction.

The experience from this pilot project will be used by the individual client and in a more general discussion of building in the future.

CONCLUSION

Experience in Denmark shows that the client can play a very important role with respect to the extent of building damage. Through active and systematic work, cases of building damage have been almost halved over a period of five years.

Action is needed in the following areas:

- the building needs must be carefully mapped together with the coming users, and the financial consequences must be assessed at an early point of time
- declarations from the designers can be used to ensure that experience concerning building damage is put to good use
- the client must play an active role in the transition between design and construction, and
- the work at the building site must be monitored and the completed building must be evaluated.

THE QUALIHAB EXPERIENCE – BENEFITS AND DIFFICULTIES OF A QUALITY PROGRAM IN BRAZILIAN HOUSING CONSTRUCTION

Francisco Cardoso, A. G. Vivancos, C. N. Jesus
University of Sao Paulo, Civil Construction Engineering Department; Sao Paulo Brazil.
francisco.cardoso@poli.usp.br

Some aspects of the process of implementation of a quality program in progress in the State of Sao Paulo, Brazil, conducted by the low-income housing office of the State, the so-called *QUALIHAB Program*, is primary discussed in this paper. It is based on case studies carried out in 1998, 1999 and, most recently, November of 2000, involving several companies and construction sites.

The most evident actions of this program are the *QUALIHAB* Qualification Systems, that are quality certification systems based on the ISO 9000:1994 standards and adapted to the characteristics of the local building construction industry. *QUALIHAB* Qualifications are now required by *CDHU* in its bidding processes. In course since 1996, the program involves more than 300 certified general contractors – GC and 50 construction management companies – CMC.

Benefits and difficulties of the implementation of the program are pointed out from the *CDHU's*, the GC's and the CMC's points of view. Some malfunctions of the *QUALIHAB Program* are discussed. Moreover, corrective actions for the *Program* are indicated, which can be considered as good references for similar programs. In Brazil, for example, the experience of *QUALIHAB* has been very useful for the implementation of a national quality program in the housing construction industry, the so-called *PBQP-H*.

INTRODUCTION: THE QUALIHAB PROGRAM

This paper aims to present some practical aspects and results of a quality program that is being implemented in the State of Sao Paulo, Brazil, to the local supply chain of the housing sector. The *QUALIHAB Program* - *QUALI* is a contraction of quality, and *HAB*, of housing - is based on the purchasing power of a common client of these actors, the low-income housing office of the State, *CDHU* (*Companhia de Desenvolvimento Habitacional e Urbano do Estado de São Paulo* – State of Sao Paulo's Housing and Urban Development Company). These results are expressed in terms of benefits and difficulties of the implementation of the *Program*, and also in terms of the effectiveness of its implementation in site operations. It does not concern cost aspects, even if this is one of the major themes of the CIB Conference. It is not a traditional academic paper; nevertheless the research that supports it has resulted of an agreement celebrated between *CDHU* and the University of Sao Paulo.

The *CDHU* contracts, on average, fifty thousand housing units per year (Feb. 2001), on three hundred financial operations. It's annual budget is about one and a half hundred million dollars (2000). Brazil has approximately 170 millions inhabitants (2000) and a housing deficit of almost five million units, eight hundred thousand of them in the state of Sao Paulo (1991). The construction sector share in the Gross Domestic Product – GDP is about 9,8% (it is the second largest sector of the economy in the country), which corresponds to more than one hundred billion dollars. The State of Sao Paulo represents almost 40% of the Brazilian GDP.

Through the *QUALIHAB Program*, *CDHU* aims to optimise the quality of housing with regard to the materials and services used in their products' conception and implementation. The Program is based in partnerships with the main actors of the sector through agreements. These agreements ponder: the implementation of specifics quality programs, the maximisation of the rate profit x cost and the satisfaction of the customers.

A particular characteristic of these agreements is that they have been negotiated by the *CDHU* with the different associations acting in housing operations. For instance, after a negotiation period, the general contractors' - GC associations, which are the most affected agents up to now, set up an agreement with *CDHU* in order to create a quality assurance system that has been included in *CDHU's* procurement processes since July 1998. This system is based on the 1994 ISO 9000 Standards and includes the "level of qualification" concept. It has only 11 requirements, once some of the ISO original ones have been abandoned and others have been mixed, simplified or adapted. The same kind of negotiation has been done with the construction management companies' – CMC association, from witch another set of requirements has been accorded. Both agreements included the so-called Sector Quality Program - SQP, which concerns also aspects like training and normalisation.

The step-by-step progression is a major characteristic of the *QUALIHAB Program*, that allows firms to adjust themselves to the accorded requirements, offering them the necessary time for self-development, while creating the educational conditions that induce them to progress in the improvement of their quality management system. It can be considered as a preparatory model to the ISO 9002:1994 certification. In the same way, the proactive characteristic, which aims to create an environment that leads firms to a certain degree of qualification, is another major aspect of the *Program.*

Figure 1 illustrates the major ideas related to the agreement celebrated between *CDHU* and the GC's associations. Table I shows the 11 requirements of the *QUALIHAB* Qualification System for GC. A first particular point of this system is the compulsory characteristic of some of its requirements, particularly the 5.1 Controlled materials and 5.2 Controlled processes for production. In fact, the *CDHU* has established, in accordance with the GC's associations, the 34 most important materials (in terms of messes and costs) and the 25 critical processes for production (also chosen according to messes and costs, while keeping a consistency with the controlled materials), for which it obliges firms to defined and to apply control procedures.

The second particular aspect is the evolutionary characteristic of some of its requirements, present, for instance, in 5.1 and 5.2. It means that the GC does not need to establish and to hold up to date all the procedures, at the same time, in the beginning of the process, to assure that all the materials and processes for production are in accordance to the specified requirements. The solution was to establish a progressive process of development, during the 30 months that have been fixed by de agreement from the level Engagement up to the level A.

In the level C, GC should have established 6 procedures for materials control and 4 for processes for production control; in the level B, 16 and 12; and in the level A, 34 and 25.

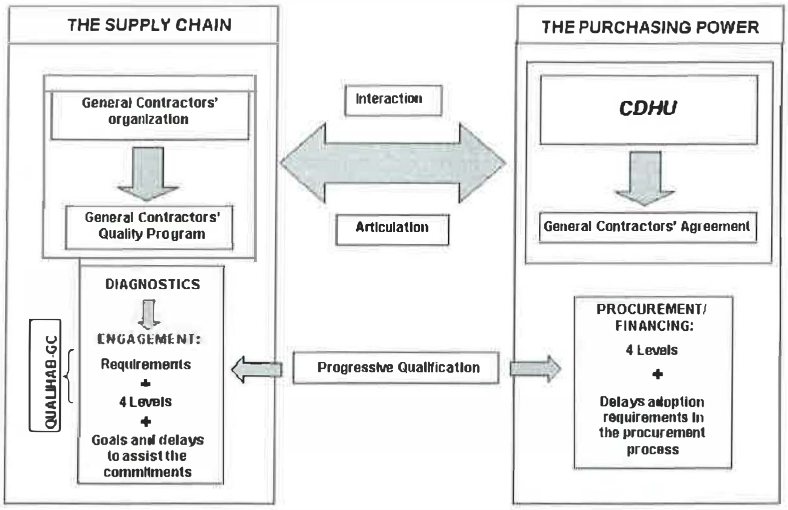


Figure 1. The interaction between the actors of the supply chain of the housing construction sector and the *CDHU*, consolidated by means of an agreement. Example for the general contractor's case (*QUALIHAB-GC*) (source: Cardoso *et al.*, 2000b).

The definition of the requirements of each level followed a particular logic:

- the "Engagement" level simply requires the engagement of the GC; nevertheless, it is an important step, once it is when the firm recognizes the *Program* and becomes part of it;
- in the "D" level, the GC begins to conceive the quality management system that it is going to put in work; the firm is also obliged to achieve an internal diagnostic;
- the "C" level probably characterizes the most difficult moment of the process, once site works are involved for the first time, through the implementation of the first materials' inspection and control and production processes' procedures; it represents a real cultural revolution for the sector, especially in Brazil;
- in the "B" level, the quality management system reaches news functions within the firm (conception, biding, documents and records) and within the construction sites (purchasing procedures, evaluation of suppliers, handling and storage of materials, preservation of products achieved); requirements concerning training also begin in this level, for the controlled "material and processes for production" (evolutionary);
- finally, in the level "A", the quality management system is concluded, through the writing of the Project Quality Plans and of the Quality Manual.

Other than these two agreements, *QUALIHAB Program* has many others celebrated either with associations of agents of the same nature of GC and CMC or with "Material, Components and Systems - MCS" associations. The first category of agreements involves associations from architects, laboratories, topographic services, and foundation subcontractors firms. Some of the "MCS" associations involved are, for instance, those that represent producers of cement, lime, prefabricated products, ceramic products and tubes and plastic components. In these former agreements, the technical clauses are based on the objectives and principles of product certification. Before requiring that only certified products should be employed in *CDHU* projects, the *Program* has foreseen some intermediate levels, based on the idea of progressive quality control of production lines. So far, almost 20 different agreements have been signed, all of them based on the principles shown above.

Table I. The clauses of *QUALIHAB* Certification System for GC and the level of certification when they are required.

QUALIHAB SYSTEM FOR GC		LEVEL OF CERTIFICATION				
	CLAUSES	ENGAGEMENT	D	C	B	A
1. Responsibility of the direction	1.1 Engagement of the firm	X	X	X	X	X
	1.2. Coordination of the Quality and Management Representative		X	X	X	X
	1.3. Quality Policy		X	X	X	X
	1.4. Responsibility, authority and means (evolutionary)			X	X	X
	1.5. Management review					X
2. Quality System	2.1. Diagnoses of the firm		X	X	X	X
	2.2. Quality planning		X	X	X	X
	2.3. Projects' Quality Plan					X
	2.4. Quality Manual					X
3. Control of documents and Records	3.1. Control of documents				X	X
	3.2. Control of records				X	X
	3.3. Traceability					X
4. Contract and conception Review	4.1. Design review				X	X
	4.2. Contract review				X	X
5. Specifications and control of materials, production processes and control	5.1. Controlled materials (evolutionary)			X	X	X
	5.2. Controlled processes for production (evolutionary)			X	X	X
6. Purchasing of materials and services	6.1. Process of purchasing and subcontract				X	X
	6.2. Assessment of suppliers and of subcontractors				X	X
7. Inspections and test status					X	X
8. Handling, storage, preservation, packaging and delivery	8.1. Control of handling and storage of materials				X	X
	8.2. Preservation of products achieved				X	X
	8.3. Final inspection and test				X	X
	8.4. Delivery and instructions for use and maintenance					X
9. Control of nonconforming products and corrective actions	9.1. Control on nonconforming products					X
	9.2. Corrective actions					X
10. Internal quality audits						X
11. Qualification and training (evolutionary)					X	X

In both agreements focused in this paper (the GC's and CMC's ones), the commitments negotiated have stand that the "levels of qualification" should be progressively required in the procurement phase of *CDHU* contracts. Since January 2000, the upper level is necessary.

The technical referential has been adapted and written to the construction reality and, as a consequence, does not respect the requirements of the ISO 9000 Standards. In consequence, it has been necessary to create specifics certification bodies rules to permit the qualification of the firms, as they are made only by third-parties audits carried out by accredited independent auditing service organisations. Moreover, the assignment of a qualification is a privilege of the Assignment Commission of the certification body, composed of representatives of the GC's or CMC's associations, of neutrals technical associations and of the customers.

More information about the *QUALIHAB Program* can be found in: Cardoso *et al.* (2000b); about the *QUALIHAB-GC*, in: Cardoso (1997) and Cardoso *et al.* (2000a); about quality management in the Brazilian Construction Industry and about the *QUALIHAB Program* impacts in Vivancos; Cardoso (2000). Finally, it can be said that the *QUALIHAB* was inspired in a French successful experience in adapting the ISO 9000 Standards requirements to the Building scenario: the QUALIBAT System (Sycodés, 1996/97; Archambault, 1995).

THE EXPERIMENT: THE PDCA CIRCLE

Both the agreements defined that, after two years their celebration, the effects of the SQP to the improvement of each actors' reality and of the effectiveness of the committed rules on the quality improvement of products should be reviewed. Indeed, in November 2000, and considering the PDCA circle (Juran; Gryna, 1988) applied to the *Program* itself, it can be said that the PLAN and de DO steps had already been done, but not the CHECK and ACT ones:

PLAN:
- creation of the *QUALIHAB Program*;
- definition of the General Contractors' Quality Program;
- definition of the Construction Managers' Quality Program;

DO:
- implementation of Quality Management Systems (QMS) in GC and CMC;
- creation of specifics certification bodies rules;
- certification of the QMS of both GC and CMC by certification bodies;
- inclusion of the accorded deals in *CDHU's* procurement processes;

CHECK:
- measurements of the implementation of the QMS in the construction sites;
- measurement of the impacts of the *Program* in the *CDHU* products;
- measurement of final customer's satisfaction;
- identification of the problems concerning certification bodies;

ACT:
- corrective actions: improvements in the SQP's (requirements, training and normalisation) and in the certification bodies rules.

The PLAN step was conducted with the participation of both *CDHU* and the associations and both these actors, also with the participation of the certification bodies, conducted the DO step. During the DO step, in 1998, when *CDHU* began to included in it's procurement processes the necessity of the certification, the Company decided to perform a primary CHECK phase, to investigate if firms were able to answer to the requirements and, eventually, to change the scheduled phases, from level D to level A. *CDHU* has engaged the University of Sao Paulo to conducted this initial phase, which has been done in 1998-99. The research group has then visited ten GC, analyzing both their offices and their construction sites. The investigations were conducted during levels D-C and C-B transitions. The most important consequence of this action was the adjournment of 3 months in the agreed implementation period of the level B. In this paper, this action is not described, nevertheless, in the final CHECK step, the experience of that period has been integrated in the methodology adopted.

CDHU was the only responsible for this final CHECK step and the Company is having the complicity of the associations and of the certification bodies to the ACT step, that will be partially analyzed here. To perform the CHECK and ACT steps, *CDHU* developed three kinds of actions: i) realization of site visits (CHECK); ii) discussions with the certification bodies about the problems found during their audits (ACT); iii) discussions with the associations and with the certification bodies to define corrective actions (ACT).

In this way, in the final CHECK step, ten visits have been done, at the end of 2000. The sites have been chosen among the 102 available, in the way that all the ten CMC engaged by *CDHU* should be visited, without repeating any of the 45 GC working at that moment. Two research groups conducted the visits, one from the University of Sao Paulo and another from the *Instituto de Pesquisas Tecnológicas* group, another important research center of the state of Sao Paulo. Each group visited five work sites, and was supported by the *CDHU's* technical staff. This paper considers the most important results of the five visits conducted by the University of Sao Paulo group. It should be said that, using a different methodology than in 1998/99, all the visits have been done without preventing the firms. In March and April of 2001, two other sites have been visited, in the way of trying to measure the improvements made by the CMC actions concerning their QMS effectiveness, and also to visit two new GC.

A questionnaire was developed for the conduction of the technical visits, which focused in the inspection of the effectiveness of the QMS implementation. The questionnaire involved not only the investigation of the attendance of the requirements but also the quality of the housings. The groups have not visited the companies' offices, but only construction sites. This is one of the reasons why the visits can not be considered as audits but only as technical visits. The major objectives were the evaluation of the firms' real practices concerning the application of QM concepts and tools and the evaluation of the quality of housing.

Nevertheless, it was difficult to evaluate the housing quality and the quality of the parts of housing in work – as the structures, masonry, plumbing, etc. – in an objective way, since norms or codes like the Anglo-Saxon's Codes of Practices or the French's *Documents Techniques Unifiés* do not exist in Brazil. This difficulty has been enhanced, once the *CDHU* also does not have this kind of product specification.

Finally, one major meeting has also been conducted with the certification bodies, to discuss their point of view concerning all the aspects listed above. The measurement of final customer's satisfaction has not been done by the *CDHU* up to now.

THE RESULTS UP TO THE PRESENT: THE "CHECK" STEP

The Effectiveness of the CMC's Quality Management Systems – QMS

The implementation of the CMC's QMS effectiveness can be considered very limited. In fact, even if the interlocutors found in the sites during the visits could not answer all the formulated questions, in the way of complementing the documentation analysis and the observed facts, in most cases, the group could not find objective evidences to demonstrate the complete QMS implementation. Moreover, the poor quality of the final products themselves showed the inefficiency of the QMS implementation.

The major tools employed by the CMC were generic checklists, which did not fix control parameters, as tolerances, for instance. Indeed, many of the control points depended on the way that the site engineer or the foreman conceived an "acceptable quality" degree. This has in part resulted of the weakness of the *QUALIHAB* Qualification System for Construction Managers (*QUALIHAB-CM*), witch requirements are very far from the ISO 9002 ones.

Another point touched the integration between the CMC's QMS and the GC's QMS, witch was almost null in many cases. Even if sometimes the GC had a specific quality management plan adapted to the site conditions (Project Quality Plan), this plan was not reviewed by the CMC. In other words, the control parameters of the GC were not validated. It must be said that CMC play a technical role on the sites, in the way they control, in the place of the *CDHU*, not only aspects like costs and schedule, but also quality ones.

The Effectiveness of the GC's Quality Management Systems

Even though the observed effectiveness of the implementation of the QMS of the GC was better than that of the CMC, the group also identified many problems, including, in many cases, the absence of objective evidences to demonstrate the complete QMS implementation. The absence of critical analyses by the CMC's of the GC's QMS and of a real engagement of the GC in quality inspection routines, associated with the weakness of the GC's QMS implementation, may justify the verified poor quality of the final products.

In most cases, the GC's actions focused the formalization of their QMS – by means of documents as procedures, records, etc. -, with an emphasis on the materials specifications, controls and storage, and with a very small effect to the products themselves. The main reason for that was the gap between the texts themselves and the reality in the field: workers and even foremen were not correctly trained to apply the procedures. This problem was amplified by the intensive use of subcontractors. Another major problem concerned the absence of Project Quality Plans adapted to sites conditions.

In both cases – GC and CMC -, the group was not able to identify "systemic" actions, as correctives and preventives actions, control of nonconforming products, evaluation of subcontractors, measurement of the performance of the QMS or internal quality audits.

The Impacts on the Products

The results of the visits already mentioned concerning the real implementation of the QMSs of both GC and CMC on the construction sites could anticipate their impacts on the products. In fact, the improvements of the quality of housing, witch was not so good before the *QUALIHAB Program*, still remains limited. It can also be said that cost reductions, thanks to productivity gains and to quality improvements, were very limited, for both firms, for *CDHU* and, manly, for its final clients.

The Problems Concerning the Certification Process

The visits, the meeting conducted with the certification bodies, and also the experience of the members of the Assignment Commissions allowed the identification of three majors points concerning the certification process: i) the large interval between two audits: twelve months, other than six suggested by ISO recommendations; ii) the fact that certification bodies have been tolerant, with the approval of both *CDHU* and Assignment Commissions, concerning site construction audits, as, in many cases, they have accept to make audits in other than housing operations, where many of the exigencies of the *QUALIHAB Program* could not be checked; iii) the absence of a clear referential concerning a minimum expected product performance, expressed by documents like Codes of Practices. A positive aspect concerns the existence of homogeneous audits procedures, defined by the two certification bodies according *Qualihab* certifications at that time, with the approval of *CDHU*.

SOME PARTIALS RESULTS: THE “ACT” STEP

The weak effectiveness of the *QUALIHAB Program* concerning the implementation of the QMS and the weak improvement of housing quality was in a certain way a chock not only to *CDHU*, but also to the associations. Some meetings have been conducted with all the actors to discuss the problem and to find ways of improving the process, as previewed in the PDCA methodology.

The major corrective actions were: i) the development, by the *CDHU*, of documents like the Codes of Practices, which will objectively define the *CDHU's* expectations for housings; these documents may be used as a reference by the certification bodies to improve their audits; ii) the integration of these new technical requirements in the Sector Quality Programs of both CMC's and GC's cases; iii) the creation of a local program concerning GC' and subcontractors' workers and foremen training, covering quality management, technical and managerial aspects; iv) the improvement of the *QUALIHAB* Qualification System for CMC (*QUALIHAB-CMC*), resulting in document that may be more similar with the ISO 9000 requirements, and also the *QUALIHAB* Qualification System for GC (*QUALIHAB-GC*); v) the reduction of the interval between two audits from twelve to six months; vi) the growth of the certification bodies working with the *QUALIHAB's* requirements number; vii) the definition of common procedures concerning audits check lists, auditor profiles and audits duration. Moreover, the suggestion of the adoption of the ISO 9000:2000 requirements, adapted to the construction reality, is seen as a future step of the *Program*.

CONCLUSIONS

The conclusions will deal with two aspects: i) the reality observed in the visits and the actions that have been or will be conducted to overcome the problems; ii) the importance and the consequences of *QUALIHAB Program* to the local supply chain of the housing sector. Concerning the second point, the major aspects are: i) since 1998, the *QUALIHAB* Qualification Systems have been adopted by almost three hundred firms, mainly GC; ii) almost 50% of these firms are not *CDHU* supplier, showing the interest of the methodology to the implementation of QMS; iii) these implementations, either in the *CDHU* market or in the private ones, are deeply changing the relationship of GC with their suppliers, with a very important forward linkage effect in the local supply chain; the backward linkage effect, affecting the relationships between GC and their clients in a positive way, is also an unanswerable fact; iv) pushed by *CDHU* or by the CG themselves, other actors in the supply chain are also concerned with this movement (as foundation subcontractors, topographic services firms, architects, laboratories and materials industries).

More than this, not only the *CDHU* projects, but also others, including the private sector, have been affected in a positive way by the *QUALIHAB*. In fact, the Program is more than a driving force to the actors, acting as a motor of quality improvement of housing, as it is now beginning to spread all over the Country, by means of the national program *PBQP-H*.

Like *QUALIHAB*, the *Programa Brasileiro da Qualidade e Produtividade do Habitat – PBQP-H* (Brazilian Quality and Productivity Habitat Program) aims to improve quality, productivity and even innovation of the social housing sector. The two major differences between *QUALIHAB* and *PBQP-H* are (Cardoso *et al.*, 2000b): i) *PBQP-H* is a national program, dealing with national projects, looking for national solutions for the commons problems found in the supply chain, all over the Country; ii) it understands *housing* in a broad way, meaning *habitat*, and deals with the implementation of services other than the housing units themselves, as streets and roads, utility networks (for water, electricity, etc.).

As a natural consequence of the *QUALIHAB Program*, but also pulled by market forces and by political decisions, *PBQP-H* was created in 1998, and is co-ordinated by the State Secretariat of Urban Development (*SEDU-PR*), directly related to the President of Brazil. The underlying principles of the purchasing power of the State and of the partnerships with the main actors of the sector have also been adopted here. Nevertheless, here there is not a single client like *CDHU*, but a set of them, in the three levels of the Brazilian Government field of action: municipal, regional (each of the 26 Brazilian States) and federal ones. The most important "client" is *Caixa Econômica Federal - CEF*, a Federal Bank of Savings and Loans, with an annual budget of more than 2.2 billion dollars, which financed two hundred and eighty thousand new houses in 1999 – for instance, in the State of Sao Paulo, from June 2001, CG must have the level D qualification of *PBQP-H* to receive *CEF* founds. The same ideas are now being discussed in the *Mercosul and Chile Quality and Productivity Housing Forum*, a meeting that will be hold for the fourth time in June 2001, in Uruguay.

Concerning the reality observed in the visits and the actions that have been or will be conducted, the first point to mention is the *CDHU* proactive and courageous attitude, in the way the Company has conducted an investigatory procedure that has reveled some weaknesses of the *Program*. The final objective was to improve it, through a continuous process of negotiations with the associations.

There is no responsible for the weaknesses but partners to overcome them. Then, the solutions must be found by every actor concerned, by means of the ACT step actions, as seen before. In fact, all the actors, the *CDHU* included, think that, notwithstanding the good principles of the *QUALIHAB*, but mainly due to its complexity, many of the problems were natural ones. Nevertheless, some of them are real problems, related either to intrinsic characteristics of the *Program*, that were identified and are being adjusted by *CDHU*, the associations and the certification bodies, or to the firms, GC and CMC. Indeed, this is a major point of reflection: in which way the compulsory characteristic of the *Program*, by means of the purchasing power of *CDHU*, is responsible for them? Are there other advantages for GC, for CMC and even for industries in this setting? This paper does not intent to answer these questions, but brings elements for their discussion.

Concerning the quality problems observed in the products, they cannot be used as an argument against the principles of the QMS or to refuse de interest of the ISO 9000 Standards certifications or of actions as the *QUALIHAB Program* ones. In fact, the quality problems should first of all be imputed to the inefficiency of the QMS of the firms, as their implementations on site were very problematic.

Finally, it is clear that the *QUALIHAB Program* has been built over good foundations, with a great motivation of the *CDHU*, of the associations and of the firms. It is now a mature program, which leaves an evolutionary moment, from which it will contribute to the progress of housing in social, economic and technological directions.

ACKNOLEDGEMENTS

The authors would like to thank *CDHU*; the contractors' associations – SindusCon-SP and APEOP; the construction managers' association – Sinaenco; and CAPES Foundation.

REFERENCES

[1] ARCHAMBAULT, G. (1995). Certification qualibat. Le tournant décisif (The Qualibat Certification. The Decisive Turn) in: *Sycodés informations*. Paris, Qualité Construction, n° 29, Mars-April 1995, pp.11-17.

[2] CARDOSO, F. F. (1997). QUALIHAB: un programme pour améliorer le logement social au Brésil (*QUALIHAB: a Program to Improve the Social Housing in Brazil*). Sycodés Informations - Qualité Construction, Paris, 1997(45), November-December 1997, pp. 12-16.

[3] CARDOSO, F. F.; VIVANCOS, A.G.; SILVA, F. B. & ALBUQUERQUE NETO, E. T. (2000a). The Qualihab Program and the New Contracts and Contractual Relationships between Firms in Brazil. In: SERPELL, Alfredo (edited by). *Information and Communication in Construction Procurement*. PUC, Santiago, 2000. Proceedings of the CIB W92 Procurement System Symposium, Santiago, Chile, April 24 – 27, 2000, pp. 233-247.

[4] CARDOSO, Francisco ; REZENDE, Marco Antônio ; BARROS, Mercia ; de OLIVEIRA Roberto (2000b). Public Policy Instruments to Encourage Construction Innovation: Overview of the Brazilian Case. In: MANSEAU, André; SEADEN, George (Edited by). Innovation in Construction. An International Review of Public Policies. Spon Press, Chapter 6, pp.61-97.

[5] JURAN, J. M.; GRYNA, F. M. (1988) Juran's quality control handbook. 4th edition, Ed. McGraw-Hill, 1988.

[6] Sycodés Informations (1996/97). Critères du référentiel de certification QUALIBAT (I à VII). Sycodés Informations - Qualité Construction, Paris, 1996-97 (34 up to 40), mai-juin 1996 à janvier-février 1997.

[7] VIVANCOS, A. G. & CARDOSO, F. F. (2000). Impacts of the Implementation of Quality Management Systems in the Organizational Structure of Brazilian Building Construction Firms. In: CIB Task Group 36 – Quality Assurance International Conference on Implementation of Construction Quality and Related Systems: A Global Update, Lisbon, Portugal, 19-21 June 2000, pp. 85-93.

DETECTING THE INDIRECT COSTS ASSOCIATED WITH REWORK IN A BUILDING CONSTRUCTION PROJECT

T. Haupt
University of Florida USA

P. E. D. Love
School of Architecture and Building, Deakin University, Australia

P.-E. Josephson
Dept. of Building Economics and Management, Chalmers Univ. of Technology, Sweden
theoc@ufl.edu

The paper discusses indirect costs associated with rework in building construction projects. It uses a case study to determine the influence that indirect rework costs have on various project participants. It identifies factors: at individual level such as stress, fatigue, absenteeism, de-motivation, and poor morale; at organisational level such as reduced profit, diminished professional image, inter-organisational conflict, loss of future work and poor morale and at project level, such as work inactivity and end-user dissatisfaction. Based on the findings from this case study it is suggested that the incidence of rework can have a multiplier effect of up to five times the actual (direct) cost of rectification. To reduce these costs it is argued that design and construction organisations must improve their quality management systems by including a system for continuously tracking, analysing and presenting direct, as well as indirect rework costs.

Keywords: Rework, indirect cost, multiplier, contract documentation, defects.

INTRODUCTION

Rework can adversely affect the performance and productivity of design and construction organisations. It is a major contributing factor to time and cost overruns on construction projects (Love, 2001). Numerous studies have attempted to quantify the direct costs of rework in building and engineering projects (e.g. Burati *et al*., 1992; Barber *et al*., 2000). Barber *et al.* (2000) have noted that when indirect costs are also taken into account the total cost of rework can be as high as 25% of contract value. A number of factors contribute to this finding that include project characteristics such as quality management practices, project type, procurement method form used, and project complexity. Since there are various interpretations as to what constitutes rework, there is a lack of uniformity in the way in which rework cost data has been collected (Gluch and Josephson, 1999). Until there is a degree of consistency in definition and calculation of rework then those rework costs that have been reported in the normative literature should not be considered to be indicative but used as a source of reference (e.g., Barber *et al*., 2000). Notwithstanding, in itself measurement of rework costs does not cause improvement — it is merely the starting point for establishing new knowledge (Love and Holt, 2000). The success of project management is based upon an ability to become scientific, where knowledge is characteristically acquired through systematic observation, experiment and deductive reasoning.

To date there has been limited research that has sought to determine the indirect costs of rework in Australian construction projects. With this in mind, this paper uses a case study to determine the influence that indirect rework costs have on various project participants. Based on the findings from this case study it is suggested that the incidence of rework can have a multiplier effect of up to three to five times the actual (direct) cost of rectification. To reduce the costs of rework it is suggested that design and construction organisations implement a quality management system, which is supported by a quality cost system. Only when organisations begin to measure (and therefore really understand) their rework costs, will they fully appreciate the economic benefits of achieving quality. That is, 'getting it right first time' provides tangible economic benefit to the entire project coalition, as well as satisfying the client's aspirations.

DEFINING REWORK

Often terms such as quality deviations (Davis *et al.*, 1989; Burati *et al.*, 1992), non-conformances (Abdul-Rahman, 1995), defects/errors (Josephson and Hammarlund, 1999), quality failures (Barber *et al.*, 2000), and repairs are used to infer rework. Ashford (1992) defines rework as "the process by which an item is made to conform to the original requirement by completion or correction". The Construction Industry Development Agency (1995), however, defined rework as "doing something at least one extra time due to non-conformance to requirements". Similarly, Love and Li (2000) defined rework "as the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time". Repairs may also involve rework, as since they are defined as "the process of restoring a non-conforming characteristic to an acceptable condition even though the item may still not conform to the original requirement"(Ashford, 1992). Essentially, rework can result from errors, omissions, failures, damage, and change orders throughout the procurement process (Love and Li, 2000a).

REWORK COSTS

Josephson and Hammarlund (1999) reported that the defect/error costs of residential, industrial and commercial building projects range from 2.3% to 9.4% of their project cost. Similarly, Love and Li (2000a) in their study of rework costs for a residential and industrial building found the costs of rework to be 3.2% and 2.4% of contract value, respectively. Josephson (1999) found no correlation between low error cost and the use of formal quality management systems. However, Love and Li (2000b) found that when a contractor implemented a quality assurance system in conjunction with an effective continuous improvement strategy, rework costs were found to be less than 1% of the contract value.

The costs of quality deviations in civil and heavy industrial engineering projects, however, have been found to be significantly higher. Burati *et al.* (1992) studied nine major engineering projects to determine the cost associated with correcting deviations to meet specified requirements. The results of their study indicated that, for all nine projects, quality deviations accounted for an average of 12.4% of the contract value. Nylén (1996) found that when poor quality management practices were implemented in a railway project, quality failures were found to be 10% of the contract value. A significantly lower figure was reported by Abdul-Rahman (1995) who found non-conformance costs (excluding material wastage and head office overheads) in a highway project to be 5% of the contract value. He specifically makes the points that these costs may have been significantly higher in projects with poor quality management.

Rework can also originate from change orders (Knocke, 1993: Love and Li, 2000a). However, the extent to which change orders contribute to rework costs remains relatively unexplored. Research undertaken by Zeitoun and Oberlander (1993) found that the median costs of change orders for 71 fixed price projects were 5.3% of the contract value and 6.8% for 35 cost reimbursable projects. Similarly, research undertaken by Cox *et al.* (1999) in the UK revealed that the costs of design-related change orders could range from 5% to 8% of the contract value even when projects are managed effectively. Most of these changes are initiated by clients. The costs of change orders in the research reported by Zeitoun and Oberlander (1993) and Cox *et al.* (1999) are similar to the rework costs previously reported. A degree of change can be, and to a certain extent, should be, expected in construction, as it is difficult for clients to visualise the end product that they procure. However, almost all forms of rework (with exception of that caused by weather, etc.) are preventable, since poor management of the design and construction process typically causes such costs to occur. While there has been a plethora of research that has sought to determine the direct (tangible) costs of rework in construction, the indirect (intangible) costs of remain unexplored. This is because it is difficult, if not impossible, to quantify such costs in pure monetary terms. Campanella (1990) reported that the Westinghouse Electric Corporation found that a *multiplier effect* of at least three to five was directly related to the indirect effects of a quality failure (e.g. rework).

The Construction Industry Development Agency in Australia (CIDA 1995) estimated the direct cost of rework in construction to be greater than 10% of project cost. If a 10% rework value was applied to the annual turnover of the Australian construction industry in 1996, estimated at $43.5 billion per annum (DIST, 1998), then the direct cost of rework can be approximated at $4.3 billion per annum. Assuming the indirect costs of rework are three to five times the actual cost of rectification, then the indirect cost of rework could range from $12 to $20 billion dollars! The negative impact on profits indirect rework can have serious consequences on costs of a project's and an organisation. For example, once design errors or omissions are identified in contract documentation, rework will occur. This process may continue to magnify until ultimately, the design firm finds itself in serious financial difficulties due to prolonged impact of an unheeded increase in rework costs, coupled with a declining performance image and low morale.

METHODOLOGY

Besides the research undertaken by Josephson and Hammarlund (1999) and Love and Li (2000a) little is known about the causes and costs of rework in building projects, particularly the indirect costs. In fact, most research has tended to focus on civil engineering projects (Davis *et al.*, 1989; Burati *et al.*, 1992; Abdul-Rahman, 1995; Nylén, 1996; Barber *et al.*, 2000) and housing (BRE, 1981; BRE, 1982; NEDO, 1987; Hammarlund, *et al.*, 1990; Hammarlund, and Josephson, 1991). To determine the indirect costs of rework there is a need for a methodology that would enfranchise those project participants that had been involved with a particular rework event so that the full impact of rework could be ascertained. Considering the originality of the research, a case study was adopted (Hakim, 1987). A description of the case study project used is presented below.

Case Description

The case-study project consisted of two, 6-storey residential apartment blocks, containing a total of 43 units. Underground parking, a landscaped podium and swimming pool were among the facilities incorporated into this development. The contract was $A11.0m, with a contract period of 43 weeks. The project was procured using a traditional lump sum contract, with the client employing a project manager to act as their development representative.

Data Collection

Data was collected from the time construction commenced on-site until the completion of the defects liability period. Interviews (unstructured and semi-structured) were conducted with the site management team, consultants, subcontractors and suppliers. The project was visited three times a week throughout its duration. Two block visits of four days to each project were included. These block visits were undertaken during times of increased site activity. Interviews were primarily used to determine those causes and effects of rework. Direct observations, and documentary sources provided by the contractor, consultants, subcontractor and suppliers were also used to derive data. Numerous other sources such as variation lists, site instructions, day work sheets, extension of time claims and non-conformances contributed to identifying rework events. These were used to determine the costs associated with rework.

Case Study Validity

The use of interviews, documentary sources, and observations requires that internal validity be addressed. Interviews, in particular, were used to identify rework events, which had been discovered during the interviews and through observations that had been made by the researcher. Each interview was tape recorded and subsequently transcribed. These were given to each person that had been interviewed to check and resolve any discrepancies that may have arisen and eliminate any interviewer bias. Bearing in mind the array of evidence that was accumulated, great care was undertaken by one of the authors to ensure that the data collected converged on similar facts as described by Jick (1979).

FINDINGS

To illustrate the multiplier effect, examples of rework that occurred as a result of poor contract documentation and workmanship are presented in detail below. With the exception of the contractor, all organisations involved in the project did not have a quality management system and quality cost system in place.

Poor Contract Documentation

Requests for information (RFIs) in terms of time were costly for all concerned with the procurement of the structural steel sub-contract. For example, the draftsman raised a total of 90 RFIs; the sub-contractor raised 20; and the contractor 15. In total, 125 RFIs were raised and the number of queries on each RFI varied from one to 20. Over a two-month period, the contractor estimated that they had spent a total of one-week dealing with the problems associated with the structural steel sub-contract. In addition, the project architect estimated that they had employed a graduate for two months, working full time, answering RFIs. Similarly, the structural engineer had a graduate engineer provide answers on a part-time basis to RFIs throughout this period. The costs of dealing with RFIs can be quantified to some degree, but the costs associated with losses in productivity, the negative effects on morale and stress, loss of income, are more difficult to obtain and even more difficult to quantify. For reasons of confidentiality, both the architect and engineer were reluctant to comment in detail about the impact that rework had on their organisations' indirect costs. However, considering the time that was spent addressing RFIs for each of the aforementioned participants, and using the costs for staff provided by the contractor, the indirect cost associated with labour was estimated to be:

(i) Project Manager @ $11,000 (on-costs) per month	$A2,538
(ii) Graduate Architect @ $4,000 (on-costs) per month	$A8,000
(iii) Graduate Structural Engineer @ $6,000 (on costs) per month	$A6,000
Total	$A16,538

Spending to correct and modify design changes, errors and omissions during the contract, will inevitably reduce a firm's profit margin. The architect and structural engineer stated that their fees for the case-project were low because they had tendered competitively for their commission. This should not have influenced the quality of service provided. Hoxley (2000) has stated that while fee levels have fallen since the introduction of competitive fee scales, service quality has not declined, which suggests that profitability has fallen and/or consultants have become more efficient. In fact, poor documentation has always been an area of concern in projects, even before fee scales were abolished (Dalty and Crawshaw, 1973; Crawshaw, 1976).

Because the documentation process was not co-ordinated by the client's representative the contract documentation produced for the case-project contained errors and omissions. When these errors were identified, design documentation was revised on a sporadic basis, as and when there was spare resource capacity in the drafting office. The proliferation of administrative costs was considered to be a symptom of poor documentation for all parties involved, for example in the procurement of the structural steel sub-contract. These particularly took the form of costs relating to additional telephone calls, faxes, letters, duplication of drawings, and couriers. While these costs may appear to be relatively minor, they can have an adverse impact on a firm's cash flow, especially if the firm were small. In the case of the drafting firm, they estimated that the costs for copying and couriering drawings to the contractor, architect and structural engineer increased their typical monthly expenditure by threefold for these items. The architect and structural engineer suggested that productivity and employee morale had been adversely affected by having to constantly revise their documentation. The architect suggested that in some instances they had to re-design elements because of errors in the structural documentation. This could have been avoided if the documentation process had been effectively managed from the outset.

The drafting firm also experienced a decrease in productivity and morale as a result of having to constantly ask for more information from the architect. Some staff, who were employed on a part-time contract basis, resigned and obtained jobs with another drafting organisation. They had become frustrated with having to rework their drawings and wait for information to arrive. The most significant indirect cost related to the extension of their original contract period of the drafting firm for the project. This affected their capacity to take on any new contracts. For deadlines to be met when information was made available, additional resources had to be employed and overtime paid. This subsequently had a negative impact on the morale of all employees within the drafting office. It was estimated that the total additional cost of rectifying the shop drawings because of design changes, errors and omissions, was $16,000.

The contractor and draftsman stated that the production of poor quality documentation was not an industry problem, but rather, an organisation-specific one. The draftsman stated that before tendering their services they took into account their previous experience with the consultants involved. The draftsman stated that they often refused to tender for a project if they are to work with a particular consultant or, if the consultant has a record of producing poor quality documentation. In such instances they typically added 10% to the value of their tender. In this particular case, the drafting firm was not familiar with the consultants involved. They stated that in future they would only deal with consultants and contractors they had worked with previously. This attitude underlined their dissatisfaction. There is the danger that recurring documentation errors will creep up and settle in at an insidiously comfortable level, being accepted as an industry 'norm'. An analogy with plant management can be drawn here. If plant maintenance costs do not increase significantly on the last year's costs, then they are generally accepted as 'normal' – regardless of whether they are artificially high – or not (Edwards *et al*, 1998). If design consultants repeatedly produce error-induced rework, they may become invisible or come to be regarded, with complacency, as the cost of doing business. Whatever percentage increase is taken up by rework, that percentage will be added to a design firm's costs.If rework accounts for 10% of regular work of a design firm, this would lead to everything being increased by 10%, namely supervision, cycle time for administrative procedures, answering RFIs and so on. The time element obviously translates into costs, which are then buried in what would be considered normal operating costs.

Poor Workmanship

It was found that defects accounted for 1.5% of the total cost of rework experienced in the case-study project. Defects were those items that were identified by the architect and project manager during their walk around the site prior to issuing the certificate for practical completion. In total, 100 minor defects were identified. Essentially, these related to the cleaning and removing of stains to the parquetry flooring in units, replacing damaged tiles to the suspended ceiling in the foyer area, and replacing damaged ferns to landscaped areas. The project manager estimated the cost of rectifying these to be $5,000 and suggested that each defect would cost approximately $50 to rectify.

The defects identified may appear minor and relatively inexpensive to rectify, but the indirect costs associated with them were significant. For example, while walking round the site with the project manager prior to the issue of the certificate of practical completion, numerous marks and unpainted patches could be seen on the walls of various units. As a result, the foreman requested that the sub-contractor return to site, because the purchaser was eager to move into the now 'finished' apartment.

The subcontractor complained to the project manager that he had to travel over 25 Km to rectify the damage that another sub-contractor had done. While ignoring the fact that they had also to return, to attend to some patches of their own work, which were considered of poor quality, the sub-contractor stated "*it's taken nearly half a day to fix this up. An hour-half here in peak hour traffic and an hour back just for an hour's work, and nobody pays for your travelling time*". When the sub-contractor was probed they estimated the indirect cost of rectifying the defect to be:

(i) Waiting and travelling time (3 hours @ $35 per hour)	$A115
(ii) Additional materials (1½ Litres of paint @ $20 per litre)	$A 30
(iii) Loss of productivity (4 hours @ $35 per hour)	$A170
Total	$A315

Considering the direct cost of rectification was $50, then the indirect cost was found to be five times this amount. Assuming that was the case for each defect, the indirect cost for defects identified for the case-study project may well have exceeded $25,000. However, most contractors acknowledge and understand the difficulties of asking sub-contractors to return to site to rectify defects. To minimise any disruption to a sub-contractor's workload they invariably attempt to package defects so that as many as possible can be rectified in one visit. There are also physiological and psychological consequences associated with undertaking rework. For example, increased stress due to the additional financial burden and the loss of profit, as well as having to do something again can have de-motivating consequences. This is especially true when a sub-contractor has to rectify somebody else's poor or unfinished work.

Once practical completion was issued most purchasers requested to move into their units. It was revealed that the development's sales staff had encouraged purchasers to do this without consulting with the contractor. Once practical completion is granted the contractor's liability with respect to time and liquidated damages and public liability ceases, and also the defects liability period commences. In affect this is the date upon which the transfer of the risk of the property to the client is effected. The contractor found it difficult to organise for many of the subcontractors to return to site to rectify defective and incomplete work, as most were working on other projects.

Consequently, some work such as re-installing general purpose outlets, sanitary appliances, re-installing locks to doors, and painting, had to be undertaken after purchasers had moved into their units. Many of the purchasers found this to be an inconvenience and consequently blamed the contractor for incomplete and poor quality work. The intangible costs to the contractor's image are greater than may at first be appreciated. Ineffective communication on behalf of the client's representative was the primary contributing factor of this disruption to purchasers. The need for effective intra- and inter-organisation communication in construction has been previously underlined (Holt *et al.*, 2000). The case in point is evidence of this assertion. If the contractor had been given a schedule of dates in advance for when purchasers wanted to move in, then completion of their respective units could have been programmed better. As it was, many sub-contractors had to re-visit the site to rectify work on an *ad hoc* basis, with adverse effects on their productivity and morale.

DISCUSSION

A summary of the indirect costs of rework experienced in the case study project can be seen in Figure 1.

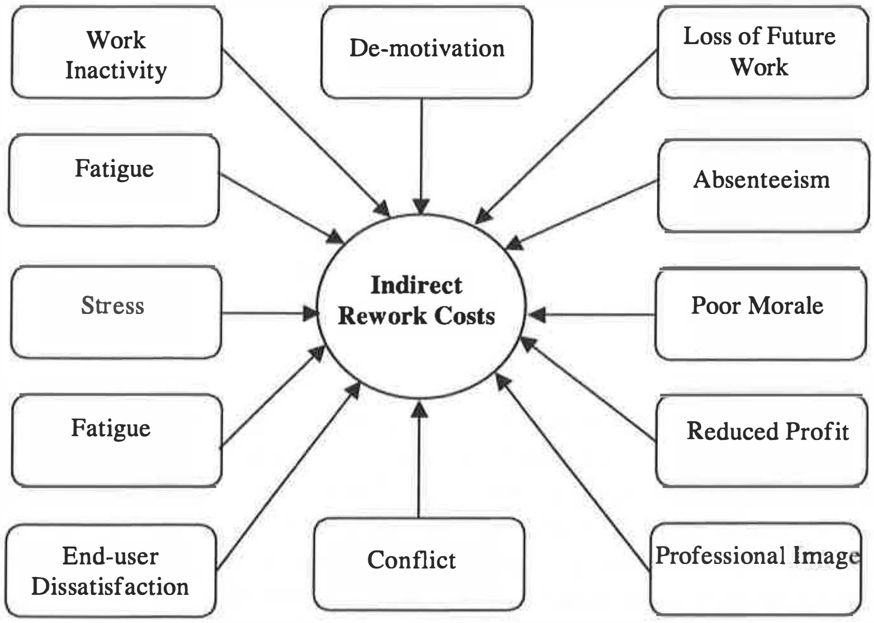


Figure 1. Indirect costs of rework

It is impossible to set aside a monetary value for each of the factors that have been identified. However, it is important to realise that rework can seriously affect the performance of an individual, an organisation and a project. At the *individual level*, stress, fatigue, absenteeism, de-motivation, and poor morale were found to be the primary indirect consequences of rework. In fact, when an individual is subjected to working longer because of errors, changes or omissions, fatigue and stress may emerge, which can increase the likelihood further rework occurring. At the *organisation level,* reduced profit, diminished professional image, inter-organisational conflict, loss of future work and poor morale were identified as indirect consequences of rework. At the project level, *work inactivity* such as waiting time, idle time, and travelling time and end-user dissatisfaction were identified as indirect consequences of rework. Cooper's (1992) rework cycle will be used to gain a further understanding about *how* and *why* rework occurs and how it can have a multiplier effect, specifically in relation to the production of contract documentation.

Rework Cycle

Figure 2 illustrates the rework cycle for the production of contract documentation. The boxes in Figure 2 represent activities that are undertaken during the contract documentation process. At the start of the documentation phase, all activities will invariably reside in a pool of work to be undertaken. As designers begin the documentation process, changing levels of *staff* (people) working at varying *productivity* (output) levels may determine the progress of the work being undertaken (Abdel-Hamid and Madnick, 1991). This is especially the case when involved staff either leave the design organisation (turnover) or become unavailable for example (due to illness or recreational leave) and replacement staff are needed to complete the documentation process. The discontinuity of design staff can have a significant impact on the performance of the design process (Chapman, 1999). This situation arises is because all knowledge and information that a staff member has acquired about the project cannot be passed directly from one individual to the next, even if a hand-over period and/or de-briefing occurs from the departing staff member (Chapman, 1999). Even staff recruited from the same office cannot acquire project knowledge immediately they commence work on the project.

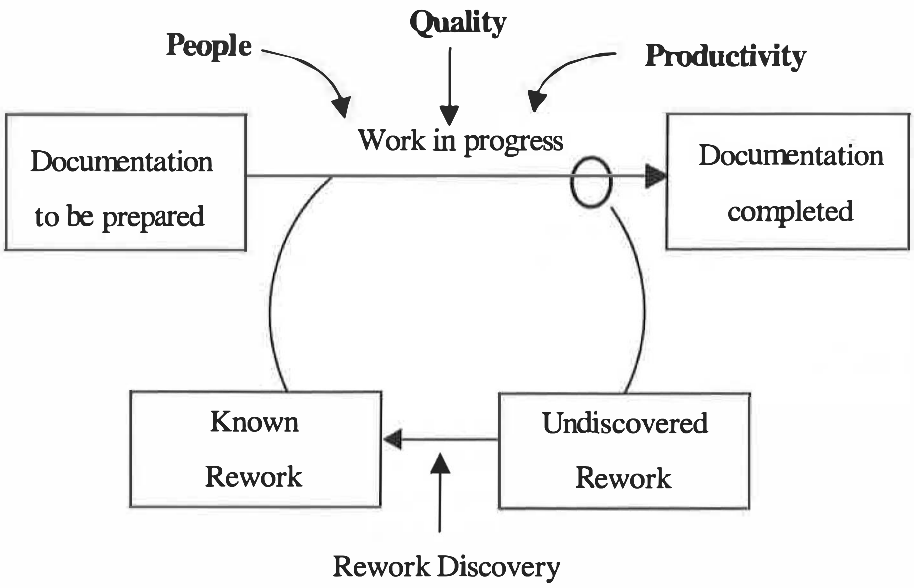


Figure 2. The structure of the rework cycle (Adapted from Cooper, 1993:p.17)

In practice, documentation activities are executed at varying levels due to the skill and experience of the designer. Consequently, this is likely to impact the *quality* of documentation produced. The completeness and level of documentation quality that is achieved depends on many factors and conditions in the organisation and the project environment (Love *et al*., 2000). For example, these may include the design firm's workload, the design fee value, time allowed for the design process, staffing levels, the amount of time allocated to prepare documentation and the procurement method. Documentation that is considered to be of adequate quality will enter the pool of documentation that is completed, which may not need re-doing unless the client or contractor requests changes to the design. Design changes may cause schedule pressures placing designers under considerable stress, potentially resulting in poor morale, conflict and fatigue due to overtime. Detailed explanations of the impact that rework (or changes) can have on productivity can be found in Moselhi *et al.* (1991).

The remaining completed documentation will subsequently need some rework, but for a period of time the documentation remains in the pool known as "undiscovered rework". This pool contains undetected errors and is therefore perceived to be error free. However, errors and omissions may be discovered in several ways. For example, through design checks and reviews, during the preparation of Bills of Quantities by the quantity surveyor or on-site by contractor/subcontractor. The rework discovery period may occur over weeks, months or even years later (depending on the size of the project) during which time dependent work may have incorporated these errors. Once discovered, the known rework will have to be addressed, which may require additional resources or overtime to be undertaken.

In addressing the identified rework, it will enter the flow of work in progress, and will be subject to similar productivity and quality variations. In addition, there is a chance that reworked items may flow through the same cycle. Indeed, poor quality contract documentation may cause more cycles of rework, requiring additional resources to rectify them. Design organisations that are not able to produce good quality documentation will not be able to maximise their return from fees. The rework cycle can also be applied to activities being undertaken on-site. Errors and omissions can affect contractor and subcontractors the same way in which they affect design organisations, especially if preliminary items such as supervision, scaffolding, and cranage are required for extended periods. Clearly, there is a need to implement effective strategies to prevent the occurrence of rework in projects that have an adverse impact on individual, organisational and project performance.

CONCLUSION

Organisations in the construction industry must realise that quality improvement results in cost improvement. Simply paying higher fees to design consultants will not reduce rework *per se*, as designing and constructing a facility right first time will always cost less. Solving problems by identifying their causes and eliminating them can result in measurable savings and improved processes. If construction organisations are to capitalise upon these savings and improvements they must implement and continuously improve their quality management systems. In addition, these systems must also be supported by a quality cost system so that identified rework causes and costs, and appropriate prevention strategies. Only when organisations begin to measure appreciate their direct and indirect rework costs, will they really understand the economics of quality. The study discusses effects from rework at individual level, organisational level and project level. Rework involves extra costs for customers, the firm and society, such as higher taxes. Considering this, it becomes necessarily more important to improve the quality management systems to reduce rework.

REFERENCES

[1] Abdul-Hamid, T.K., and Madnick, S.E. (1991). *Software Project Dynamics. An Integrated Approach.* Prentice Hall, Englewood Cliffs, NJ.

[2] Abdul-Rahman, H. (1995). The cost of non-conformance during a highway project: a case study. *Construction Management and Economics*, 13, pp.23-32.

[3] Barber, P., Graves, A., Hall, M., Sheath, D., and Tomkins, C. (2000). Quality failure costs in civil engineering projects. *International Journal of Quality and Reliability Management* 17(4/5), pp.479-492.

[4] Building Research Establishment (1981). *Quality Control on Building Sites*. Current Paper 7/81, HMSO, London.

[5] Building Research Establishment (1982). Quality in Traditional Housing – An Investigation into Faults and their Avoidance. BRE, Garston, UK.

[6] Burati, J L, Farrington, J. J., and Ledbetter, W. B. (1992). Causes of quality deviations in design and construction. *ASCE Journal of Construction Engineering and Management*, 118(1), pp. 34-49.

[7] Campanella, J. (1990). Principles of Quality Costs: Principles, Implementation and Use. ASQC Quality Press, Milwaukee, WI.

[8] Chapman, R. J. (1999). The likelihood and impact of changes of key project personnel on the design process. *Construction Management and Economics*, 17, pp.99-106.

[9] CIDA (1995). *Measuring Up or Muddling Through: Best Practice in the Australian Non-Residential Construction Industry.* Construction Industry Development Agency and Masters Builders Australia, Sydney, Australia, pp. 59-63.

[10] Cooper, K. G. (1993). The rework cycle: benchmarks for the project manager. *Project Management Journal*, 24(1), pp.17-21.

[11] Cox, I.D., Morris, J., Rogerson, J.H., and Jared, G.E. (1999). A quantitative study of post contract award design changes in construction. *Construction Management and Economics*, 17(4), pp.

[12] Crawshaw, D.T. (1976). *Co-ordinating Working Drawings.* Building Research Establishment, Current Paper CP 60/76, Watford, UK

[13] Dalty, C.D., and Crawshaw, D.T. (1973). *Working Drawings in Use.* Building Research Establishment, Current Paper CP 18/73, Watford, UK.

[14] Davis, K., Ledbetter, W.B., and Burati, J.L. (1989). Measuring design and construction quality costs. *ASCE Journal of Construction Engineering and Management*, 115, pp.389-400.

[15] DIST (1998). *Building for Growth.* A Draft Strategy for the Building and Construction Industry. Department of Industry, Science and Tourism, Commonwealth of Australia Publication, February, Canberra, Australia.

[16] Edwards, D., Holt, G. D. and Harris, F. C. (1998). *Maintenance Management of Heavy Duty Construction Plant and Equipment.* Oxford: Chandos Publishing Ltd.

[17] Gluch. P. and Josephson, P.-E. (1999) *Evaluation of methods for studying environmental errors in building and civil engineering projects.* In Proc. Nordic Seminar on Construction Economics and Organization, 12-13 April 1999, Gothenburg, Sweden, pp 137-144, Göteborg: Chalmers University of Technology.

[18] Hakim, C. (1987). Research Design: Strategies and Choice in the Design of Social Research. Allen and Unwin, London.

[19] Hammarlund, Y., Jacobsson, S., and Josephson, P. (1990). *Quality failure costs in building construction.* Proceedings of the CIB W55/W65 Joint Symposium, International Council for Building Research Studies and Documentation, Sydney, pp.77-89.

[20] Hammarlund, Y., and Josephson, P. E. (1991). *Sources of Quality Failures in Building.* Proceedings of the European Symposium on Management, Quality and Economics in Housing and other Building Sectors. Lisbon, Portugal, September 30th - October 4th, pp 671-679.

[21] Hoxley, M. (2000). Are competitive fee tendering and construction professional service quality mutually exclusive? Construction Management and Economics 18, pp.599-605.

[22] Josephson, P.-E. (1999) Effective management of building production. In Proceedings Joint Triennial Symposium CIB Commissions W65 and W55, 5-10 September 1999, Vol. 2, pp. 706-715. Cape Town: CIB.

[23] Josephson, P-E., and Hammarlund, Y. (1999). The causes and costs of defects in construction. A study of seven building projects. *Automation in Construction*, 8(6), pp.681-642.

[24] Jick, T.D. (1979). Mixing qualitative and quantitative methods: triangulation in accumulation. *Administrative Science Quarterly*, 24, pp.602-611.

[25] Knocke, J. (1993). *Post Construction Liability and Insurance.* E & F Spon, London, UK.

[26] National Economic Development Office (1987). *Achieving Quality on Building Sites.* pp.18-19.

[27] Love, P. E. D., Mandal, P., and Li, H. (1999). Determining the causal structure of rework in construction projects. *Construction Management and Economics* 17(4), pp. 505-517.

[28] Love, P.E.D., and Holt, G.D. (2000). Construction business performance measurement: The SPM alternative. *Business Process Management Journal* 6(5), pp. 408-416

[29] Love, P. E. D., and Li, H. (2000). Quantifying the Causes and Costs of Rework in Construction. *Construction Management and Economics,* 18(4), pp.479-490.

[30] Love, P.E.D., Mandal, P., Smith, J., and Li, H. (2000). Modelling the dynamics of design error induced rework in construction. *Construction Management and Economics,* 18(5), pp.575-586.

[31] Love, P.E.D. (2001). The influence of project type and procurement method on rework costs in construction projects. *ASCE Journal of Construction Engineering and Management* (Forthcoming)

[32] Moselhi, O., Leonard, C., and Fazio, P. (1991). Impact of change orders on construction productivity. *Canadian Journal of Civil Engineering*, 18, pp.484-492.

[33] Nylén, K-O. (1996). *Cost of Failure in a Major Civil Engineering Project.* Licentiate Thesis, Division of Construction Management and Economics, Department of Real Estate and Construction Management, Royal Institute of Technology, Stockholm, Sweden.

[34] Sörqvist, L. (1998) *Poor Quality Costing*, Doctoral thesis No. 23, The Royal Institute of Technology, Department of Materials Processing, Production Engineering, Stockholm, Sweden.

[35] Zeitoun, A.A., and Oberlander, G.D. (1993). *Early Warning Signs of Project Changes.* Source Document 91, Construction Industry Institute, The University of Texas at Austin, Austin, Texas, USA.

TIME IS QUALITY – THE USE OF INNOVATIVE CONTRACTING TECHNIQUES FOR TIME REDUCTION IN TRANSPORTATION PROJECTS

Zohar Herbsman, Ana Maria Ellias, and Cristina Cosma
Department of Civil Engineering, University of Florida (USA)
zjh@ce.ufl.edu

For many years the time element was not the most important element in construction or transportation projects in U.S.A. and many other countries. The element of cost was the most important one, and therefore the procurement systems were mainly for materials and equipment.

In the last ten years, the transportation industry has shifted from building new roads to construction of existing facilities. Those projects are mainly in urban areas and cause substantial delays to the traveling public. The economic cost of these delays is enormous. For example, in a project in California the cost of delay was estimated at $ 200,000 per day. In order to minimize those delays, a few innovative procurement systems for "buying time" were introduced in U.S.A. The common denominator of all those procurement systems is the ability of the contractor to procure the time for completion of the project.

The paper will describe the advantages and disadvantages based on the experience gained from over one hundred transportation projects. The paper also will discuss the analytic method to calculate the cost of a time unit, which is the key element for those innovative systems. Finally, the paper will present three case studies in which contractors were able to complete projects ahead of schedule using those innovative techniques.

Keywords: procurement, time unit cost, road user cost, , bidding methods, transportation projects

INTRODUCTION

Today's highways have become such an integral part of our daily lives that over 90% of America's total transportation needs are met by these systems (Highway, 1992). Unfortunately, this heavy traffic has had an undesirable effect of decreasing ability of each motorist to effectively utilize this country's transportation network. In the past two decades, the number of vehicles on our roadways has increased by more than 75% while the total mileage of new highway systems has increased by only 4% (Highway, 1992). As a result, the traveling public inevitably faces heavy traffic congestion, especially in the metropolitan areas. Therefore, increasing usable roadway lanes for vehicular traffic has become one of the top priorities of all state highway agencies (SHAs) across the nation.

To effectively meet the growing need for additional usable highways, attention is shifting from the building of new transportation facilities to the resurfacing, rehabilitation and restoration (3R's) of those already in existence. Typically, these projects are undertaken in heavily urbanized areas, causing extreme traffic congestion during the construction period. This slowdown of the traffic flow not only poses severe inconvenience to the traveling public, it also negatively impacts the business community. With such a premium placed on construction time, many of this country's SHAs have begun to implement alternate construction procedures in an attempt to reduce project duration. A variety of contacting and bidding methods have been introduced in the United States over the last several years that specifically address reduction of construction times by "buying time". The four most popular of these methods presently being utilized are:

- Bidding on cost/time
- Incentive/disincentive (I/D)
- Bidding on cost/time combined with incentive/disincentive
- Lane rental

Each of these four innovative methods considers the value of the time. Due to the significant influence of time value, schedulers will have to become much more proficient in estimating construction times. It is therefore a necessity for the successful practitioner to become familiar with the basic principles and procedures of these developing contracting methods.

TIME VALUE

Unit Time Value

Each of the innovative procurement methods addressed in this paper is based on the principle of cost reimbursement to the contractor for contract time reduction. To ascertain these costs, the owner has to calculate what is the value of the time. For example, if a contractor reduces construction time by 40 calendar days, the owner has to determine what is the value of the 40 calendar days of time reduction. In this case the owner is a "time seller".

Calculation of time value is based on a parameter defined as "unit time value" (UTV), which represents the value of a time unit to the owner. In most cases, the UTV will include the direct cost resulting from construction delays, such as temporary facilities, moving costs, and another alternate solutions. Indirect cost items and a variety of other general costs can also be considered in the UTV calculation. The measurement of UTV can be in any unit that the owner chooses, such as hours, days, weeks or months. The total value of the time to be sold is calculated using formula in Equation (1):

$$TTV = UTV \times T \qquad (1)$$

Where: TTV = total time value;
UTV = unit time value; and
T = time

Calculation Of Daily Road-User Cost (DRUC)

UTV calculations in the highway construction industry are typically expressed as a cost per day. This variable, evaluated by SHAs throughout the country, is commonly referred to as the "daily road-user cost" (DRUC). For example, if a new road has to be built, a feasibility study will be conducted by the SHA to determine the economic impact of the new facility. A calculation of the DRUC will be part of this analysis, and will include such items as travel time, travel distance, fuel expense, as well as other related components.

Although DRUC calculations have been performed routinely by SHAs for many years, no formal computational procedures have been instituted nationwide. Therefore, many states have developed their own procedures. One of the major differences in DRUC calculations among the various SHAs is the way in which they approach indirect costs.

INNOVATIVE PROCUREMENT METHODS

Generalities

The utilization of innovative procurement methods has increased substantially in recent years. The evaluation of these nontraditional techniques has been performed by the authors researching dozens of case studies of projects constructed under one of these contracting strategies. To be able to compare and contrast these methods, the reader needs to be familiar with the basic principles of each method. This section is devoted to describing concepts and procedures associated with each of the three most popular innovative procurement methods used in today" highway construction industry.

Bidding On Cost/Time (A + B)

Until recently, bidding on cost/time, also referred to as the A+B method, has been employed very sparingly in the United States. However, after this approach was recommended by the federal highway agency, its use has steadily increased among various SHAs.

The first step in this procedure is for the owner to establish the DRUC and incorporate it into the bid documents. Next, every contractor who participates in the bidding process will be required to calculate two values: A- the estimated construction cost for the project; and B – the estimated project duration for construction completion. The successful bidder is the contractor who submits the lowest total combined bid (TCB) using formula from Equation (2):

$$TCB = ECC + (DRUC \times EPD) \qquad (2)$$

Where:

TCB = total combined bid;
ECC = estimated construction cost for the project (the "A" in the A+B method);
DRUC = daily road-user cost; and
EPD = estimated project duration for project completion (the "B" in the A + B method).

The feedback from those SHAs who have implemented the bidding on cost/time method has been very positive (Harp 1990; Taricone 1993). Herbsman and Ellis (1992) analyzed data obtained from 14 case studies of projects contracted using the bidding on cost/time method. The results of this analysis indicated that for the most part, substantial time reduction was achieved with little or no increase in overall construction costs.

The most important advantage of this method is that time reduction is achieved through competition between contractors rather than direct monetary payments. A study of the bid results from a large number of projects has revealed that when bidding on cost/time, contractors do not appreciably raise their unit prices with respect to the unit prices of comparable projects bid using conventional methods.

The main disadvantage to notice are the problems that may arise under this method when contractors are too eager to get the job and may underestimate the construction time in order to increase their chances of being the successful bidder. When the contractor realizes that the original estimated project duration is unattainable, he might be tempted to "cut corners" in an attempts to limit financial losses. At this point, the quality of the work might suffer, and the contractor will most likely be looking to change orders and claims as a means for recouping losses.

Incentive/Disincentive

In the incentive/disincentive (I/D) method, the contract time is determined by the owner and presented as part of the bid documents. If the contractor is able to complete the project ahead of schedule, this contractor would then be entitled to a bonus (incentive fee). If, on the other hand, the contractor finishes the project behind the schedule, the owner then assesses a penalty (disincentive fee)

As was the case with the bidding on cost/time (A + B) method, the DRUC is also an integral part of the I/D method. Most SHAs calculate the DRUC and apply this value as their daily incentive/disincentive fee. A study conducted by the Iowa DOT, illustrates the distribution of I/D fees for various transportation agencies across the United States. According to the SHAs surveyed, over half of all I/D contracts let by these agencies had an I/D fee in the range of $2,500/day to $5,000/day

Different parameters are used for establishing I/D fees. One of the alternate approaches to DRUC is to calculate the I/D fee as a percentage of total project cost. The value of incentive and disincentive fee can be equal but may also differ. Many states have implemented limits to the maximum amount of I/D fees These limits, also known as caps, have been set by as a percentage of the total construction cost or as a flat-rate dollar amount. Arizona, had a limiting cap in terms of time rather than dollars (±30 days). Most of cap amounts vary depending on the project.

The main advantage of utilizing the I/D contracts are construction time reductions in almost every case. Another advantage of the I/D contracting strategy is its flexibility in enabling SHAs to adjust their financial exposure by utilizing flat rate or percentage caps for I/D fees. It has also been reported that on projects that used the I/D approach, as compared to the A + B method, the relationship between the owner and contractor tended to be much less adversarial.

This aspect is apparently related to the fact that the contractor typically receives some amount of incentive payments.

The major disadvantage of the I/D method lies in the fact that the fees are based on the engineer's time estimates, as established by the SHAs. Today, in the United States, most transportation departments determine contract time based on the performance (production rates) of the average contractor. This practice of establishing contact times creates a situation whereby a good competitive contractor can reduce contract time with little or no additional commitment of resources. In other words, the same time reduction could essentially be achieved, free of charge, by reducing the original engineer's time estimates.

Lane Rental

Introduced in the United States in 1990, the lane-rental method has been used extensively by the British Department of Transportation (BDTp) since 1984. This method was defined as a way of providing financial incentives to general contractors and others to shorten the overall time required for lane closures (Report, 1989).

To utilize the lane-rental method, the transportation agency in charge of managing the project must set contract times, as well as determine the cost of lane closures under various working conditions. Each bidder is required to submit their cost estimate of the work to be performed, along with the amount of time needed for lane closures during the construction period. The total cost of the project is the sum of the cost estimate of the work to be performed plus the cost of all essential lane closures. The lowest total aggregate cost estimate will determine who will be the successful bidder. Upon commencement of construction, whenever lane closures are required, the contractor will pay to the owner those charges in accordance with a predetermined schedule of lane closure fees.

An example of calculating lane closure fees shows that if a contractor elects to close one lane of traffic from 9:00 a.m. to 3:00 p.m. on weekdays for a total of 20 days, a cost item of $120,000 ($6,000/day x 20 days) should be included in the bid. If on the other hand, this contractor decides to close one lane from 6:00 p.m. to 6:00 a.m. during weekdays for the same amount of days, then an add of only $20,000 ($1,000/day x 20 days) would be required in the bid.

In order to avoid the payment of excessive lane closure fees, the contractor will strive to minimize construction work during the peak traffic hours. Bondar (1988) found that the contractors seem to better manage the construction work, as well as the material deliveries, thus maximizing productivity during lane closure periods, again in an effort to pay the lowest fees possible. Hence the contractor is highly motivated to minimize lane closures, and when such occurrences do arise, every effort is made to undertake these lane closures during off-peak hours.

Although the lane-rental method has been utilized on a few projects in the United States (Colorado and North Carolina), this contracting strategy is still in its infancy. Due to the continued rate of success that this approach enjoys in the United Kingdom, some practitioners feel that lane-rental method may become an established part of our highway construction industry. According to the BDTp, the average reduction of construction times realized utilizing this method is approximately 25% (Srinivasan and Harris, 1991).

The main advantage of this method, is that it allows the contractors freedom to choose the best work patterns for construction (day, night, weekend, one lane closed, two lanes closed, detour, and so on). In addition, the contractors are strongly motivated to reduce the construction time because they actually pay out (real money) to the owner for the lane closure.

The BDTp reported that the main disadvantage associated with the lane-rental was the tendency for contractors to "cut corners" when faced with the prospect of unanticipated lane-closure fees due to construction delays. Just as it is in the United States (A + B method), this situation could lead to poor quality and strained contractor/owner relationship.

CASE STUDIES

Many specific case studies have been examined in detail. The major conclusions from analyzing these case studies shows that the low bidding time was estimated and achieved by better organization, better scheduling and planning, better use of resources and not by raising the cost. However, when contractors were able to earn high incentive fees, they then invested more resources, switched to night or 24-hour day shift work, etc.

Case Study 1

An example of a highway bid tabulation from a construction project in North Carolina (Table 1) is presented. Since this project was contracted utilizing the A + B method, each contractor participating in the bid submitted an estimated construction cost, column 2 and the estimated project duration required to complete this project, column 4.

The estimated construction costs submitted by the five bidding contractors range from $19,371,550 to $21,138,086, while the estimated project duration vary from a low of 642 days to a high of 762 days. Although contractor B ranked second in both the estimated construction cost and the estimated project duration, this contractor was awarded the project by virtue of the lowest total combined bid of 424,222,537. The calculation of the total combined bid of contractor B is as follows:

$$\$19{,}518{,}537 + 672 \text{ days} \times \$7{,}000/\text{day} = \$24{,}222{,}537$$

From the general public's point of view, the state of North Carolina obtained a project with a 90-day reduction in construction time, calculated by subtracting the estimated project duration of contractor B at 672 days from the engineer's time estimate of 762 days (762 days – 672 days = 90 days). According to the North Carolina DOT's DRUC calculations, this savings of 90 days is valued at $630,000 (90 days x $7,000/day). Therefore, the net savings realized by the citizens of North Carolina utilizing the A + B method was $483,013 ($630,000 - $146,987). North Carolina DOT did not consider any indirect costs in their DRUC computations.

Table I. Bid results Utilizing the Bidding on Cost/Time (A+B) Method

Contract	Estimated Construction Cost		Total Time Value			Total Combined Bid (A + B)	
	Dollar value(A)	Rank	Estimated project duration(d)	Rank	Dollar value[a] (B)	Dollar value	Rank
A	19,371,500	1	762	4	5,334,000	24,705,550	4
B	19,518,537	2	672	2	4,704,000	24,222,537	1[b]
C	19,734,919	3	702	3	4,914,000	24,648,537	2
D	20,198,158	4	642	1	4,494,000	24,392,158	3
E	21,138,086	5	762	4	5,334,000	26,472,086	5

Note: engineer's cost estimate (A) = $20, 568,042; engineer's time estimate: 762 days
[a]Equals column 4 x DRUC ($7,000/day).
[b]The successful bidder.

Case Study 2

After the Northridge (California) earthquake, the California DOT (CALTRANS) had to reconstruct a few bridges (over crossing) which caused enormous problems (delays, loss to the business community, etc.) to the public. CALTRANS decided to use the A + B plus I/D as the best method to reduce construction time (see Table II).

In Table II information provided by CALTRANS on the Santa Monica Freeway reconstruction project is presented. The contractor did a very detailed schedule – worked 24 hours/day, 7 days/week, and used extensive resources to reduce the time. The management of the project was also very intense.

Table II. Santa Monica freeway bridge reconstruction project

Item	Data
Date:	April 1994
Budget(engineer's cost estimate):	$21,341,839
Engineer's time estimate:	140 calendar days
RUC:	$200,00/day
Contractor' s cost estimate:	$14,904,275
Contractor' s time estimate:	140days
Incentive/Disincentive fee:	4200,000/day
Completion time:	66 days
Incentive fee, 74 days x $200,000=	$14,800,000

As for the public reaction, the California trucking association reported that "operating the freeway early will save their commercial operators more than $250 per truck trip or %500,000 per day" in trucking cost (Carr 1994). This figure demonstrates the enormous value of damages to the business community caused by this type of project (3R). CALTRANS based their calculations of the RUC only on direct cost, so they arrived at the value of $200,000. If indirect costs, such as losses to the business community, were taken into consideration, the RUC value would have been much higher.

Case Study 3

The third project that was analyzed is referring to the improvement of Sheridan Boulevard in Denver, Colorado, in fall 1993. The purpose of the project was to rebuilt the Sheridan Interchange to current standards and replace the structurally deficient bridges over bear Creek and Sheridan Boulevard.

The Colorado DOT selected the lane rental method since this project was to be constructed in a heavily populated area with no detouring suitable to handle the traffic. It was felt that lane rental would provide the contractor an incentive to complete work quickly to reduce the construction inconvenience impact on the traveling public.

The lane rental fee was calculated as a road user cost for closing one lane. The data for this calculation came from a traffic survey in the area, before construction and during construction. Table 3 is an example of the lane rental fee as calculated by Colorado DOT.

Table III. Calculation of Lane rental Fee by Colorado DOT (Delay and Cost Analysis)

Kenyon Avenue Delay for existing conditions = 18.9 sec./veh. Delay for construction = 60.0 sec./veh. Difference in delay = = 41.1 sec./veh. = 0.11 hours/veh. **Bear Valley** Delay for existing conditions = 15.5 sec./veh. Delay for construction = 60.0 sec./veh. Diff. in delay = = 44.5 sec./veh. = 0.12 hours/veh. Average cost per hour delay for cars = $ 6.25 Average cost per hour delay for trucks = $17.80 Total ADT 38,600 with 4% trucks or 37,075 cars and 1,544 trucks.	**Kenyon Avenue** $37,056 \frac{\text{cars}}{\text{day}} * 0.011 \frac{\text{hours}}{\text{veh}}. * \$6.25/\text{hour} = \$2,544/\text{day}$ $1,544 \frac{\text{trucks}}{\text{day}} * 0.011. \frac{\text{hours}}{\text{veh}} * \$17.80/\text{hour} = \$303/\text{day}$ **TOTAL = $2,847/day** **Bear Valley** $37,057 \frac{\text{cars}}{\text{day}} * 0.012 \frac{\text{hours}}{\text{veh}}. * \$6.25/\text{hour} = \$2,779/\text{day}$ $1,544 \frac{\text{trucks}}{\text{day}} * 0.012 \frac{\text{hours}}{\text{veh}}. * \$17.80/\text{hour} = \$ 330/\text{day}$ **TOTAL = $2,847/day** **FINAL LANE RENTAL COST = $2,847/day**

The lane rental started after midnight September 10, 1993, and was scheduled to last 3 days. This schedule would have been met if a 5-in. snowstorm had not developed. The storm caused the contractor to go into one additional day of lane rental. The contractor was charged a total of 4 days at $2,850/day. The owner was satisfied with the results since the inconvenience to the traveling public was reduced. Colorado DOT received only two complaints from the public, which is far fewer than the number received on a similar project contracted with no lane rental closure.

CONCLUSIONS

This paper presents three innovative procurement methods that all share a common goal of reducing project duration, but each has a very different approach for achieving this common objective. The authors have analyzed a great deal of data from case studies, as well as from numerous interviews with practitioners who have been involved in innovative contracting projects. The research results indicate that the three methods can be divided into two major areas. In the first category, that includes the bidding on cost/time (A+B) method, time reduction is achieved by competition between bidding contractors. In the second category, time reduction is encouraged by financial rewards and time delays are discouraged by penalties. The incentive/disincentive (I/D) method and the lane-rental method are included in this category.

The main conclusion reached from analysis of all available research data was that each of the three methods was successful in reducing construction time. This success rate was measured against engineers' time estimates calculated as if the projects were contracted under conventional methods. Time reductions of 20-50% were achieved in comparison to similar projects using conventional contracting methods.

The most economical methods of the three is bidding on cost/time (A+B), since the time reduction is achieved through competition rather than monetary payments to the contractor.

The use of the incentive/disincentive method was determined to be less effective and more expensive than the A+B method. This would explain the decline in the number of I/D contracts let in the United States over the last few years.
The new approaches represented by the lane-rental method as well as a combined method (A+B plus I/D) are promising, however more data from additional case studies must be collected for further analysis. More studies need to be done in developing standard procedures for calculating the value of time (DRUC), especially in the area of determining what indirect cost items have to be included in the final calculations.

Additional research should be conducted with the goal of establishing an acceptable methodology for computing "reasonable" contract determination. The application of knowledge-based expert systems in this area has shown some promising results, and more research could yield valuable data.

REFERENCES

[1] Bondar, V A (1988) Lane rental: the DTP view. *Journal of Installation. of Highways and Transportation*, Vol.(35), pp.22-26.

[2] Carr, P (1994) Reducing highway congestion: Creative approaches to highway construction. *A Report by Legislative Commission on Critical Transportation Changes*, The Assembly State of New York, Albany NY, June,pp.35.

[3] Harp, D W (1990), Innovative contracting prices-the new way to undertake public works projects. *Hot Mix Asphalt Technology*, Winter, 6-0.

[4] Herbsman, Z and Ellis, R (1992) Multiparameter Bidding system-Innovation in Contract Administration. *Journal of Construction Engineering and .Management*, ASCE, Vol.118(1), pp.142-150.

[5] Highway Statistics (1992), Federal Highway Administration, Washington, D.C.

[6] Lane rental surfaces at ACPA convention, (1990), *Highway and Heavy Construction*, Mid-Jan., Vol.9.

[7] Report of the joint working group on lane rental for local authority roads (1989). *Association of County Councils*,U.K.

[8] Srinivasan, R. and Harris, F C (1991) Lane rental contacting. *Journal of Construction Management .and Economics*,Vol.9(2), Reading, U.K., 1991-195.

[9] Tarricone, P (1993) Deliverance. *Civil Engineering*., ASCE, 63(2), 36-39.

TUTORIAL SUPPORT SYSTEM AS A BASIS OF 'QUALITY AND SAFETY AND HEALTH IN CONSTRUCTION' LEARNING AND TEACHING

M. Casals, N. Forcada, F. Peñaranda, X. Roca
Dept. d'Enginyeria de la Construcció, Universitat Politècnica de Catalunya (Spain).

S. Mecca, M. Masera
Dipartimento di Ingegneria Civile, Universita di Pisa. Pisa (Italy).
nuria.forcada@upc.es

The competence acquisition in Q and S&H in construction is often the result of a self-training in practical experience. Quality and Safety and Health management pose a complex challenge to an educational system, because either the overwhelming practice and empirical knowledge component, either the high degree of general and specialised competence required.

The question is shared by more professional profile in construction, in a context in which learning resources have to match learning demands. The academic education may play a role of knowledge or learning brokers enriching their existing courses through specific innovations in content and delivery.
The basis are the educational approaches emerging , in the last decade.

The Goal and Problem Based Scenarios Tutoring is a cognitive oriented approach able to integrate the pedagogical issues of the learning by doing approach with cognitive theories that can be effectively supported by multimedia tools.

Goal and Problem Based Scenarios Tutorial Systems can be a key teaching tool to reduce the knowledge lack of actual complex process knowledge in Q and S&H courses.

The paper discuss this pedagogical approach in Q and S&H teaching, comparing it with the actual system in the European context, and presenting an on going pedagogical experimentation. It will also focuses on the cost and benefits of application this new teaching methodology.

THE PEDAGOGIC BACKGROUND FOR QUALITY AND SAFETY & HEALTH IN CONSTRUCTION

Nowadays Construction Quality and Safety & Health is a fundamental subject of Building and Civil Engineering.

From one hand, Construction Safety Management is getting more concern in construction sites due to the great deal of accidents. Accident prevention and general safety prevention require specialised competence in construction.

The organisation of prevention on site is focused on the integration of the prevention in all the hierarchical levels and in the active and responsible participation of everybody from the company (managers, workers, etc).

On the other hand, in Quality Management and Quality Assurance, the planned and systematic activities implemented to provide to the customer confidence in construction process and in Quality Control, involves both monitoring specific project results and identifying ways to eliminate causes of unsatisfactory results.

Process instability and the presence of multiple actors require a coordination of information sharing based of the different competencies.

The actual training systems are limited in the sense that they are not aimed to the solution of specific problems. The lack of experience and subjectivity does not allow to interpret concepts. Without concepts we are unable to frame experience, overcoming the specific and identifying rules, which allow to interpret reality.

OBJECTIVES OF THIS NEW TUTORIAL SYSTEM

From the beginning of the use of the Information and Communication Technologies the teaching methods and strategies are trying to get profit from this tool.

Quality and Safety & Health in Construction has acquired and will acquire growing importance. This means not only in economic terms but also from a social and environmental viewpoint and in terms of quality of life.

However, Q and S&H teaching at university does not seem to be adjusting to the educational needs of a highly dynamic and specialised, cross-sector industry.

Traditional teaching is characterised by a clear-cut division between subjects and a poor contribution of industrial practice. In university departments, especially the technical ones, the best courses tend to be those where there is a strong and deeply rooted research activity. This trend towards specialisation causes the spreading of expertise as a direct consequence.

In this Paper, we are going to describe a new tutorial support system as a basis of 'Quality and Safety and Health in Construction' learning and teaching.

This new tutorial support system has the following main objectives:

- Develop a new methodological approach to Q and S&H teaching. The traditional approach to teaching shows some deeply rooted problems due to the scarce attention paid to the student's learning processes. This reduces teaching effectiveness from the point of view both of learning time and knowledge retention.
- Formulate and experiment at European level the principles and methods for the integration of knowledge, in order to create teaching environments containing high levels of skill. As

far as contents are concerned, it will focus on the problem of cultural integration and law differences between countries. The possibility to offer educational services to students coming from different nations, with extremely different cultural and educational backgrounds involves the review of contents considering quality, quantity, and structure.

- Guarantee punctual and flexible access to knowledge. This tutorial support system aims at improving the access and use of university training resources through the application of the Information Technology (IT), both to university work and to the future educational market.

WHY A GOAL PROBLEM BASED SCENARIO APPROACH

The heart of this tutorial support system is that all courses should be constructed in the form of goal based scenarios. Students should know what the goal of the course is. As long as the goal is of inherent interest to a student, the problems are like real problems and the skills that are needed in any attempt to accomplish that goal are those that the course designer wants students to have, we have a match, and thus, a workable goal and problem based scenario.

"This idea works for adults as well, although the curricula for adults need not be play-oriented in the way it could be for a small child. When adults are asked to learn something they want to know why they should do so. Any adult curriculum should make the "why" clear right from the beginning. " (Shank 1992)

TEACHING STRATEGIES OF A GOAL-PROBLEM BASED SCENARIOS TUTORIAL SYSTEM

A tutorial system GPBS-TS should support three types of teaching strategies:

- expository,
- exploratory
- reflection.

The tutoring framework defines a precise role for both exploratory and expository teaching.

Expository teaching is used for presenting basic and highly structured instructional material (e.g. regulations, physical laws, standardised problem solving procedures, etc.) Exploratory teaching is used in open-ended problem solving. Expository teaching means that the system constrains the student through a rather fixed learning paths in a set of documents. The student starts from the beginning of the instructional material and proceeds along pre-established paths.

In **exploratory teaching** the student is given a task and a set of supporting instructional material arranged according to the set of competencies the student is supposed to acquire. The learning path is much less constrained. Competencies are represented as sets of topics and are ordered according to some practical principles. Nevertheless the student is somewhat free to navigate through the set of topics. The system coaches the student providing advice and supports to guess the most promising step.

Reflection is aimed to fostering process awareness by mirroring (objectifying) in some environment the conceptual trace of the student's design process.

The analysis of the conceptual trace of his/er own decision process increases the student's awareness about his/er status and let him/er produce better choices. Decision process traces have also other fundamental roles in the learning environment. First of all they help design communication between the student and the teacher and among collaborating students. Second, they are used by the tutoring system to fine tune the student coaching process.

Implementing a tutoring system supporting GPBS by means of exploratory and expository teaching involves a number of tightly related aspects both in knowledge representation, reasoning processes, tutoring strategies and Human-Computer interface.

The basic idea is to interleave at runtime exploratory and expository teaching so that structured instruction is transferred only when the student really needs it, that is, instruction is embedded inside a student-developed need-to-know.

CASE BASED TUTORIAL SYSTEM CHARACTERISTICS

A case based tutorial system should maintain certain characteristics of the original process, such as:

- The flowing aspect of the decision process of construction management.
- The exploration nature of project management.
- Project complexity regarding the knowledge of technology, regulations, actors, and theoretical, practical, and management procedures.
- Graduation of management tools based on the process phase, and on the uncertainty of the system state.
- The different dimensions of the required project performance (time, cost, quality).

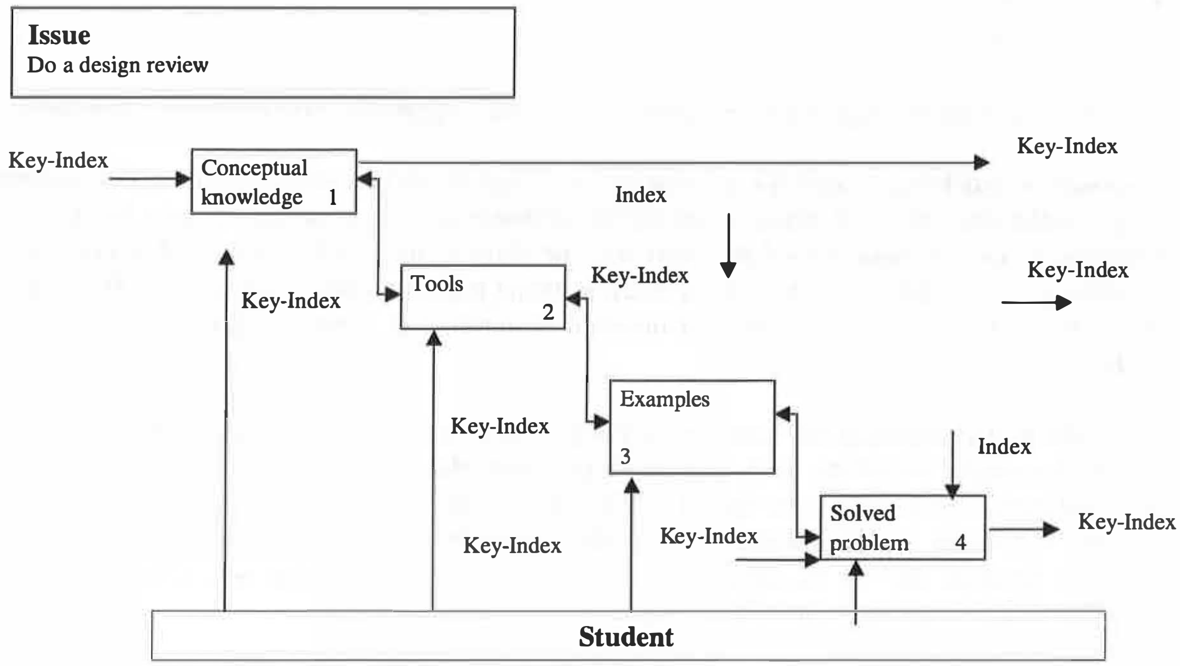


Figure 1. Courseware exploration procedure scheme

CASE BASED TUTORIAL SYSTEM LEARNING PROCESSES

The tutorial system structure can allow different learning or exploration procedure like a traditional courseware exploration procedure or an innovative case based exploration procedure according to the different needs of students or personal attitudes.

The modelling of the learning process

Simulation and role playing games require the construction of the learning process as a continuous and innovative process leading to the transformation of behavior and of enrichment of competency resources.

The goal oriented tutorial system is built as a series of scripts and aimed to allow formative processes. The training process uses case-based scripts and scripts requiring the decision making process.

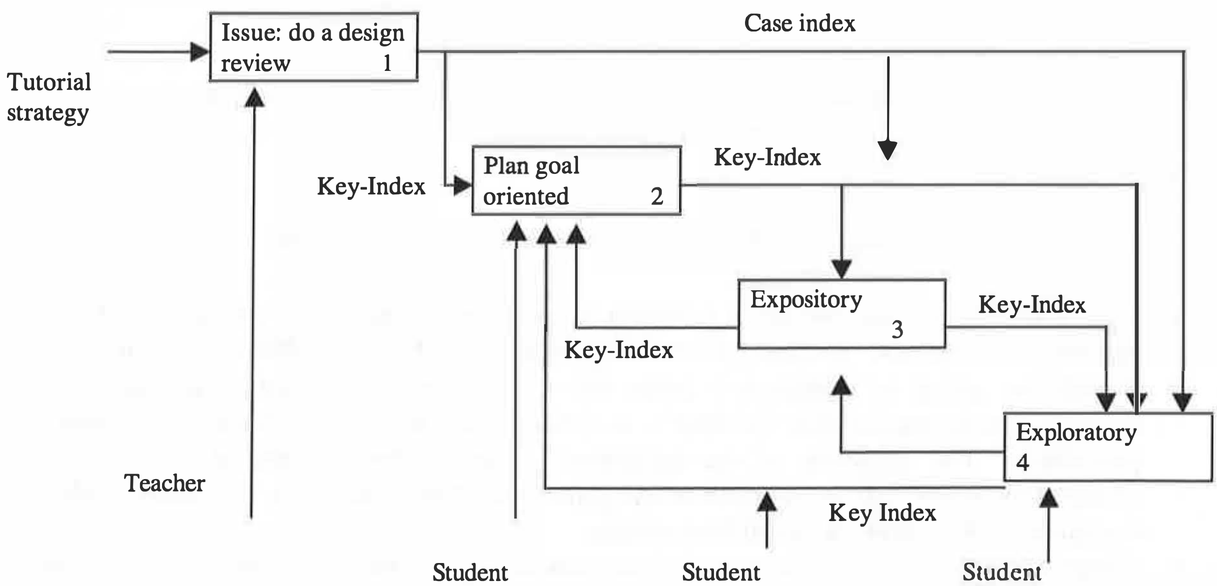


Figure 2. Case-base exploration procedure scheme

The progressive exploration is guided by the tutor according to the most appropriate pedagogic strategies or decided by the students. The aim is the development of behaviors that will improve efficiency and efficacy. Other objectives are: to improve the ability to adapt strategies to complex situations, to be able to promptly react, to check the result of the actions and to be able to coordinate with other operators that take part in the process.

Pedagogic strategies

It is always possible to split teaching and knowledge transfer methods to two possibilities: the first is a deceiving type, where is encouraged the exact reproduction of codified behaviors, precision of information and models, and the application without deviations. The second is a transformation type, which encourages quality of elaboration, single valuation of problem solution, problem solving according to personal strategies and evaluation of the used strategy.

Bruner in his book "Towards a instructional theory" underlined the usefulness of simulation as a formative tool: "The most constant problem in the social studies field is to try to divide social life happenings from the inner conscience without making them too schematic. Four techniques seem to be particularly useful for this scope. The first is confrontation; [...] the second is simulation used to make forecasts, to formulate hypothesis, and procedural thoughts. The third is participation - specifically through the use of games utilizing formal properties of the original model. In this case, the game is similar to a mathematical model - an artificial representation, often very effective, of reality. The fourth it's just the old approach based on the stimulation of consciousness. [...] Games [...] are also useful to introduce [...] the idea of a theory of these happenings." (Bruner 1973)

Role of simulation games

Such need, specific of adult students' training, can be fulfilled through the development of simulations of highly realistic projects, where each participant has an operational role. It can also be fulfilled through building learning contexts where participants may identify themselves, develop complex actions, analyze and compare the results of their decisions, use critical judgment under expert supervision and discuss their choices with operators involved in real processes.

Simulation games may assume different but compatible characterizations:

- Role-play or role game based on a system of spontaneous actions by participants facing a hypothetical situation. Without a formal structure, useful for adult students training.
- Simulation game or operational game based of more formalized procedures of the relations among participants working in an environment defined and bounded by rules and procedures. The behavior of the participants may follow competition, collaboration, rivalry, but always follow the rules of the game concerning resources, procedures, allowed decisions, and evaluation of the final results.
- Computer simulation or instrumental simulations, using probability theory, game theory, queuing theory and operational theory. It is used as tutoring tool to help the application of more complex rules, not compatible with the time frames and dynamic of the game. It is used to help the search for solutions more than the understanding of the process. Simulation may be a filter among players or a tool usable by each player to increase the speed of the game, the solution of complex calculation procedures, and the precision of the obtained results. (Taylor 1978)

These three paths are always present both in educational simulations and in real problem simulations. In the educational context role games and operational games are preferred, in the real problems context instrumental simulation is preferred. The use of one path does not exclude the use of other paths. Simulation games of different complexity levels use all three paths in their pedagogic strategies to obtain specific formative performances, such as:

- Increased students motivation in learning;
- Increased efficiency and efficacy in learning through different levels: experience in decision making, knowledge of roles and functions, interdisciplinarity of concepts, events time frames, introduction to individuation and solution of real world problems.

The uncertainty and complexity level of the problem to be solved amplifies the range of quest for procedures with similar satisfying results. Simulation games and role games should impose the framing of learning as a continuous and innovative process for the transformation of behavior and for the enrichment of competency resources. The more the case and the scenario are presented complex and uncertain, the more the models and learning schemes for the satisfying solution are required to be rich and have variety.

THE TUTORIAL SYSTEM PROTOTYPE STRUCTURE

The tutoring model supporting the training of Q and S&H in Construction, is articulated into two main parts:

- a tools kit, aiming to support student in the training. Basically they are automation office software, a Cad system, a project planning system and a networking support. Other advanced tools, introducing to an innovative practice, are: workflow and quantitative simulation software, prototyping tools for quality management, construction safety management and so on;

- a tutorial system, conceived like a netsurfing space, interfacing with the tools kit, which elements are:

  - a courseware, that is the conceptual knowledge and the theoretical topics of Q and S&H management, technical manuals and paradigmatic solved problems;
  - a base of cases and a database of cases histories, in which are stored information about historical series of data or particular pregnant and exemplar cases;
  - several scenarios in which the simulation game is posed. A scenario looks like a particular case partially known by the students and it limits the training field of them;
  - a notepad, which is a tool aiming at to trace the cognition process of the student;
  - an information basket, aiming at to help the student to bookmark the courseware used;
  - a tutorial strategy system, by means the scenarios are defined, the goals are fixed, the task are assigned, and the process cognition is monitored.

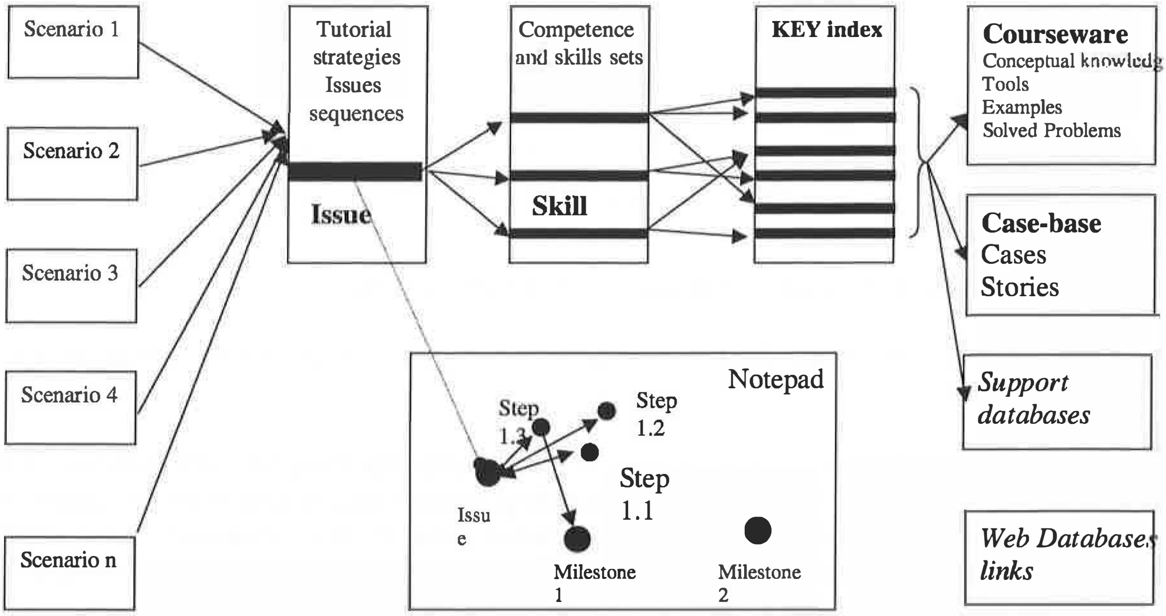


Figure 3. The Tutorial System Structure

A Tutorial System is a mean to **transfer a set of competencies** to the students. Competencies can be either prerequisites or targets. Prerequisites are competencies the student should already have in order to perform the design task.

A course unit is based on a set of **scenarios** like operational games, simulation games and role-playing games which the learning motivational frame for students.

Inside a scenario we may define **an issues sequence** which define a learning path.
Skills are related to set of topics. Topics are conceptual knowledge of the subjects involved by the competencies. Topics are used as conceptual links among competencies and from competencies to cases. The cases which are relevant to a competence are those which exemplify the competence topics.

A course unit is supported by auxiliary learning material. It can be either a set of cases or/and basic supporting information like regulations, best practices, technologies, etc. All the supporting instructional material should be indexed with the set of topics (concepts) which has been used to index the involved competencies.

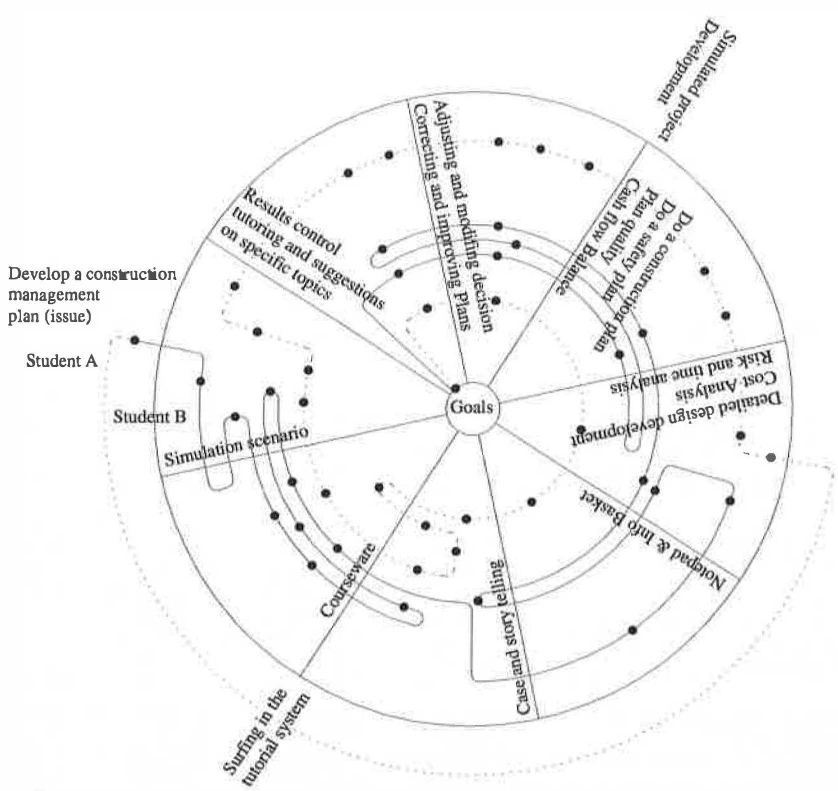


Figure 4. Different learning paths

A student is a woman or a man, that has a problem to solve. The system conception permits to follow different cognition process, tailored on the specific needs of the students. In the diagram are posed a couple of hypothetical cognition process representing the specific cognition mode of two different persons. The student A and the student B represent two opposite way of the same problem solving. The student A has a theoretical and reflexive approach, and he prefers to build a complete frame of the problem before to move. The student B approaches the solution by trial and error. Both students have to feedback more time on the decision assumed and they have to re arrange many time the research process in the tutorial space. An indexes system connect the information in the tutorial space. From the requested skills pattern and from the tutorial strategies, exercises and games are defined. The basic function of the system permit to assist the student involved by:

- the control of the consistency and the robustness of the obtained solution;
- the control of the completeness of the competencies acquired;
- the address and re-address to the relevant questions submitted;
- the custom-made adaptation of the cognition needs.

COMPARING THE CLASICAL TEACHING METHODOLOGY AND THIS NEW TUTORIAL SUPPOR SYSTEM

This new tutorial support system, contributes to meeting those social objectives of the community, that can be typically achieved by means of such a technology (among which cutting mobility costs, enhancing the quality of students' life, reducing transportation, favouring cultural integration, fostering employment and contact with industry, allowing better regional growing, etc.)

The main social objectives that can help achieve are linked (in addition to the improvement of the overall quality of graduates), to the reduction of important social costs and the gradual harmonisation of these costs.

Data published by the OECD are influenced by the great difference between the education systems in the various countries. However, here are some data available allowing a comparison about important aspects of the university education system in Italy, France, Great Britain, and Germany.

Table I. Comparing the Univ. Education Systems (Italy – France –Great Britain- Germany)

	Italy	France	GB	Germany
Students/teachers ratio (data 1997)	34.0	20.5	13.4	15.8
Techn. and adm. staff/teachers ratio (data 1997)	1.2	0.7	1.5	1.8

Cost of each graduate (data 1997)	Italy	France	GB	Germany
Cost of each graduate (Euro)	53,710	72,304	61,458	115,170
State contribution for each graduate (Euro)	45,448	58,876	45,965	79,018
state% out of the total amount	84.6	81.4	74.8	68.6

Cost of each student (data 1997)	Italy	France	GB	Germany
Cost of each student (Euro)	4,028	8,780	9,400	13,583
State contribution for each student (Euro)	3,099	7,127	6,972	9,296
state% out of the total amount	76.9	81.2	74.2	68.4

Source: CRUI on OECD and ISTAT data.

These data should be taken into consideration because they lead to important conclusions on the productivity and efficiency of the different systems of university education.
We can work out a case study about the Architecture departments in Italy. About them we have the following aggregated data.

Table II. Schools of Architecture in Italy (Data 1996/97)

Enrolled students	38,509	Total costs for each student (Euro)	5,146
Students still enrolled after the completion of the envisaged courses	48,991	Total costs for graduate (Euro)	100,000
Total amount of enrolled students	87,500	Total costs for exam (Euro)	2,004

Graduates (1996)	6,456	Envisaged duration	5 years
		Real duration (1995-96)	9.1 years

Source: CRUI on ISTAT data.

At the University of Ancona it has been demonstrated that the use of tutorial support system can lead to a reduction of at least 20% of the time required to pass a university exam of Architectural Design.

Considering that each exam costs 2,000 euros and assuming a 20% cost cut for each exam, there is a total reduction of 35,000,000 euros; this calculating only one exam per year (very prudential estimate) and only for the students of Architecture departments in Italy.

This is a very general estimate that we can very applying the approach used in other studies (e.g. Steel-CAL project). They assume that the application of such technologies produces the expectation that a 10% reduction in lectures time per student can be achieved. University lecturers' time can be then used for other purposes and, in round figures, with 90,000 students and 30 students/lecturer the 10% saving is equivalent to 300 lecturers. Assuming total costs/lecturer of 100,000 euro-year, the result is 30,000,000 euros. This is an 8-digit figure as the one given before.

These considerations refer to a case study confined only to Architecture departments in Italy and with gross estimates, but if one takes the great number of students into account that can be involved in Europe in the use of these technologies, it is doubtless that it is possible to make huge savings.

CONCLUSIONS

The entire education sector in Europe is faced with radical restructuring processes that are expected to lead to the integration between degrees, a better teaching quality, and greater opportunities to improve and update one's knowledge (life-long learning). In the field of Quality and Safety & Health in Construction this restructuring will have to be even deeper. Several things have changed: the social and productive context, materials, technologies, and laws.

The tutorial support system as a basis of 'Q and S&H in construction' learning and teaching is a new methodology to reduce the lack of knowledge in this area, increase students motivation in learning, create flexible information flows and high levels of skill, etc. It also innovates the access and use of university training resources through the application of information technology to university work and educational market promotion.

Furthermore, as it has been demonstrated in the University of Ancona, this new tutorial support system can reduce the cost of each student that can be used for other purposes.

REFERENCES

[1] ANSOFF I., 1987, Organizzazione innovativa, Ipsoa Scuola d'impresa, Milano

[2] BRUNER J., 1973, Towards an instructional Theory, Armando, Roma

[3] CHAPPELL A. R., 1991, Addressing The Trained Novice/Expert Performance Gap In Complex Dynamic Systems: A Case-Based Intelligent Tutoring System, Georgia Institute of Tecnology.

[4] FITZGERALD N., 1985, Teaching with Cases. American Society for Engineering Education Prism, pp.16-20

[5] GARDNER H., 1993, Educare al comprendere, Feltrinelli, Milano

[6] MALGLAIVE G., 1990, Enseigner à des adultes, PUF, Paris

[7] SANTONI RUGIU A., 1992, Nostalgia del maestro artigiano, Liguori, Napoli

[8] SCHANK R. C., 1992, Goal-Based Scenarios, technical Report No.36, december 1992, Institute for the Learning Sciences, Northwestern University.

[9] TAYLOR J. L., WALFORD R., 1978, Learning and the simulation game, The Open University Press, Milton Keynes

PROCEEDINGS

COSTS AND BENEFITS RELATED TO QUALITY AND SAFETY AND HEALTH IN CONSTRUCTION

TUESDAY, 23 OCTOBER 2001

TOPIC: MANAGEMENT OF CONSTRUCTION QUALITY AND SAFETY AND HEALTH COSTS.

HEALTH AND SAFETY COSTS ON THE CONSTRUCTION SITE: AN ITALIAN APPROACH

Arie Gottfried, Marco Lorenzo Trani
Building Engineering and Territorial Systems Department, Polytechnic of Milan, Italy
arie.gottfried@polimi.it

The paper presents some reflections on ways of calculating the so-called "safety costs" for a building site. Starting from a scrutiny of new statutory and regulatory provisions on the subject, the authors then identify elements of cost and arrangements for their representation within a Safety and Co-ordination Plan. Next they consider the question of cost estimates for implementing prevention and protection measures at building sites, with reference to a series of guides to be found in the literature and in regulations, and point to a set of multiplication factors for safety costs.
In conclusion, they examine the ways in which tenders' economic resources devoted to safety are handled, with reference to the various possible solutions to the question of reimbursement of these costs to the contractor, using the public works tendering industry as a model.

THE STATUTORY E REGULATORY FRAMEWORK

Until a few years ago, any mention in Italy of the "costs of workplace safety" meant looking at the problem from a strictly social point of view, and referring, in a purely negative sense, to the cost incurred by the community as a result of accidents, including fatal ones, occurring in the workplace.

The text by which EC Directive (92/57/EEC, known as the "Construction Site Directive") was incorporated into Italian law in 1996 (subsequently amended in 1999: Legislative Decrees 494/1996 and 528/1999) introduced a new concept of "costs of safety"; for it required the Safety Co-ordinator, at the planning stage, to draw up an official account of the costs of implementing the precautionary and protection arrangements, so that these could be explicitly reimbursed to the contractor who undertook construction of a project. Identical amendments and additions to the Act of 1994 (No. 109), laying down the regulatory framework for public works again stated that costs incurred for safety under the Safety and Co-ordination Plan must be shown in the call for tenders and are not subject to price competition [Dutch auctioning] in tendering by contractors.

In particular, Article 12 of Decree 494/1996 lays down that the Safety and Co-ordination Plan is to include estimates of the costs both of *"procedures, preparations and equipment for guaranteeing compliance throughout the works with accident prevention standards and regulations for workers' safety"*, and of the *"measures for the prevention of risks resulting from any simultaneous or successive presence of different firms or independent workers"*.

Article 12 also lists the elements which are to make up the Safety and Co-ordination Plan, and assigns explicitly to the Safety Co-ordinator the duty of estimating, at the planning stage and in relation to the nature of the works, the expenses that can be expected for setting those elements in place.

The draft regulations on minimum contents of safety plans for construction sites (ref.: Act 109 of 1994, Article 31(i); Legislative Decree 528/1999, Article 22(i)) give further details on these safety cost estimates that are to be developed as part of Safety and Co-ordination Plans.

COST ELEMENTS

For proper identification of the cost elements which the Project Co-ordinator must quantify, we may refer to the structure of a "standard" Safety Plan. This structure can be divided into seven sections:

- section A: site environmental conditions and surroundings;
- section B: minimum safety requirements of the site;
- section C: description of the works; works schedule
- section D: operational specifications for co-ordination;
- section E: risk evaluation specifications;
- section F: co-ordination arrangements;
- section G: estimate of costs.

The contents of Plan sections B, C, D and F, in particular, are of decisive importance in assessing safety costs.

Section B, the contents of which derive directly from the site analysis carried out for section A, shows what needs to be laid down for compliance with the minimum safety requirements which the Contractor must meet in organising his own workplace. This concerns the following:

- general precautionary measures;
- site boundaries; site enclosure
- access, thoroughfares, internal routes, traffic and parking areas;
- site services;
- stores and deposits of materials;
- fixed workplaces
- the electrical installation of the site;
- lifting gear (cranes, winches, &c.);
- waste disposal;
- handling of emergencies; attendance of emergency staff
- site sanitary arrangements;
- fire prevention;
- training of workers;
- paperwork.

Each of these elements must be taken into consideration in section G of the Safety and Co-ordination Plan.

In section C, the Co-ordinator defines in the Works Schedule a "standard" completion time for each activity to be carried out and, accordingly, the completion time for the project as a whole. The schedule drawn up in section C therefore generates two distinct lines of exploration of details in the time/cost formula: on the one hand, the Co-ordinator can establish cumulative periods for the performance of each individual activity in full compliance with safety standards, with a further conservative provision for so-called "residual risk" as well; on the other, the Co-ordinator can lay down a sequence, compulsory on safety grounds, for the Schedule's individual activities (so as to avoid their mutual interference in place or time); and this can result in a longer overall completion time for the works. The introduction of such a sequence is in fact one of the *"measures for the prevention of risks resulting from any simultaneous or successive presence of different firms or independent workers"*.

It should be noted that the increases in completion times assigned by the Co-ordinator to each activity are the result of directly observing, in the field, the frequent failure to comply with the most elementary safety standards. On this point, an investigation was carried out, on the basis of field surveys, by the Building Engineering and Territorial Systems Dept. of Milan Polytechnic, and a comparison was made of completion times for different types of floor; the increases in time necessary for guaranteeing safe performance of the same activity (e.g. worker clambering up onto a caisson as opposed to fetching a ladder and positioning it properly) were measured as falling in the range 18% - 27%.

Section D, concerning operational specifications for co-ordination, includes further details which help in estimating the costs of safety, since it illustrates specifically for each activity the *"procedures, preparations and equipment"* needed for optimal co-ordination among teams of workers so as to minimise the risk of accidents to members of other teams.

In section F, describing co-ordination arrangements, the Co-ordinator also sets out the contractor's technicians' time (and hence cost) that must be allocated to activities of site safety co-ordination.

On the basis of the material generated in earlier sections, the Co-ordinator will then be in a position to draw up section G dealing with the estimate of costs.

THE ESTIMATE OF COSTS

The cost estimate at this stage, then, assumes that a full, quantified estimate of the items concerning the safety of the site and the operations has to be carried out.

Current regulatory and statutory provisions lay down, in particular, that:

- the estimate must be appropriate, broken down into individual headings, whether flat rate or proportional to quantities; it must refer to standard or specialised price lists, or be based on official tables or lists of prices applying in the area concerned, or on the Commissioning Party's price list of safety measures;
- where no price list is relevant, or none is available, reference must be made to full cost analyses derived from market surveys;
- the individual items of safety cost are to be calculated by taking account of their cost of application at the site in question; this includes, where applicable, installation and subsequent dismantling, and any maintenance and depreciation.

For making the calculation, the following conventional principles are assumed, as suggested by research carried out by the Rome CPT (Regional Joint Committee):

- the cost of preparatory works is to be attributed in full to safety costs;
- safety features of machinery are excluded from safety costs, since they are normally regarded as necessary for ensuring that the equipment meets the proper standard;
- the re-usability of materials and equipment can be taken into consideration by having recourse to hiring and, where this is not possible, costs can be allocated *pro-rata* in relation to possible re-use, where the number of occasions of such re-use can be fixed in advance on the basis of normal site practice and the duration of the site in question;
- the cost of hourly-paid labour is to be set at the mean national value derived from official publications: it is the sum of pay, social security and insurance contributions, and attendant expenses and charges;
- machines and equipment to be conventionally classified – for the purpose of evaluating the hire cost as a function of market value and the depreciation rate – into at least four classes, depending on their practical working life:

5) class 1 (working life 72 months); this class covers: preparatory works and scaffolding, Portakabins and lock-ups; technical equipment and measuring apparatus; silos; hoppers and containers; site equipment in general; piping and similar items;
6) class 2 (working life 60 months); this class covers: electrical equipment; electric ventilators; electric compressors and pumps; workshop machinery; concrete-mixing machinery; crushing and screening machinery; i/c compressors, tractors, dump trucks; and similar items;
7) class 3 (working life 48 months); this class covers: motor vehicles; ventilation plant; drilling and wrench units (jumbo); diggers and mixer trucks; loaders and transporters; cls and spritz pumps; metal caissons, water and compressed air pipework and accessories; and similar items;
8) class 4 (working life 36 months); this class covers: light equipment for preparatory works; movable containers; mobile or portable items of electrical equipment; and similar items.

- in the case of consumable materials (used up entirely), only the purchase cost is to be shown, accounted for in full on the basis of the mean values actually charged in the market. In the case of those which can be re-used, the description should indicate the mean period of usability on which the value used must be calculated.

For every cost analysis made, each of the following should be shown in its own column:

1) the reference to the paragraph(s) of the section(s) of the Safety and Co-ordination Plan in question;
2) the code number of the analysis, in relation to cost analysis file that is created and subsequently added to; the description of the analysis and the valuation parameter(s), i.e. the cost coefficients, of which more details are given below;
3) the serial number referring to each elementary cost component entering into the individual analysis, and the corresponding code number;
4) the description of each elementary cost component;
5) the partial quantities in respect of dimensions, hours, &c., as well as the hire coefficient used (if any);
6) the total of each elementary cost component, and the corresponding unit of measurement;
7) the unit cost of each elementary cost component, per corresponding unit of measurement;

8) the partial amount for each elementary cost component (product of the total quantity and the unit price of each component);
9) the duration of application to the project, for each elementary cost component;
10) the number required for the project for each elementary cost component;
11) the total amount for the project.

It is worth pointing out here that in view of the present scarcity of reference material, Co-ordinators are forced to develop purpose-made cost analyses for hiring and materials, because of the lack of adequate information in the price-lists that are commercially available.

Once the analysis of the total quantity and unit costs, and the calculation of the partial amount, have been completed for each elementary cost component, the cost assessment then proceeds by applying these to the particular project by using two cost coefficients. The first, known as "duration of application to the project", concerns the amount of time involved in the overall duration of the activity to which the analysis refers; the second, known as "number required for the project", concerns the quantity of each component needed. For example: in the case of operations requiring the use of a wheeled drawbridge, the overall duration of use must be determined (duration of application to the project), and the number of such items of equipment needed (number required for the project).

The number required for the project is not always needed: in the case, for instance, of a movable, post-and-chain site boundary, the cost for this provision depends only on the number of months the site lasts and its geometrical size (linear metres, in this case): only these are needed. The importance of the data in section C and section D of the Safety and Co-ordination Plan becomes obvious. In particular the duration of the site (or of the activities concerned) can be deduced from the Works Schedule, which is shown in section C.

At the Safety Co-ordinator's discretion, adjustment for a specific site can be made at the planning stage with the use of additional cost coefficients. Awareness of the number and composition of the work teams involved could, for instance, make it possible to introduce a cost multiplier increasing the standard costs of site service provision (normally reckoned per worker) where the number of operators is limited.

Multiplication of the partial amount, the duration of application to the project and the number required for the project then yields the total project amount, for the cost analysis under consideration.
The cost analysis can then be usefully classified in relation to the nature of the risks diminished by the safety measures to be implemented; i.e. on the basis of the list in Article 12 of Legislative Decree 494/1996.

The sum of the safety costs from all the cost analyses yields a figure for overall safety expenditure, which we write as **SCS** [spese complessive della sicurezza]. The ratio of this amount to the overall cost **C** of the project gives the incidence of the safety cost on total project cost, written here **IS** [incidenza ... sicurezza]. Thus,

$$IS = SCS/C.$$

We should point out here that the overall project cost **C**, as understood for the present purpose, must be calculated as the sum of costs of all work necessary for completion of the project, including the costs necessary for provision of preparatory works and the implementation of measures already calculated as safety costs.

Now the descriptions given in the price lists used at present for drawing up the project specifications (on the basis of which Contractors formulate their tenders) use expressions such as "roughcast on vertical walls, laid on with interior plastering trowels, inclusive of scaffolding as required ..."; and Co-ordinators are accordingly obliged to factor out the cost of this scaffolding since by law it cannot be the object of price competition. This implies a highly detailed cost analysis, to determine, for instance, what effect on the overall cost of plastering is attributable to the cost of the trestle decking needed for putting up one square metre of ordinary plaster onto a horizontal indoor ceiling of up to 3.5m height. The existing literature in fact tells us that for each square metre of plaster we need:

- $0.015 \div 0.017\ m^3/m^2$ of plaster;
- $0.30 \div 0.35\ h/m^2$ of skilled labour;
- $0.30 \div 0.35\ h/m^2$ of unskilled labour;
- $1\ m^2/m^2$ of trestle decking.

This approach to the problem has been confirmed by the Public Works Supervisory Authority (Decision no. 2/2001), which suggests a method for arranging the calculation of the index **IS**, by dividing the expenditure **SCS** into two components, one being expenses for safety included in the unit price of individual operations and the other being the so-called "special" expenditures not included in those prices. Both components must be determined, at the stage of drawing up the Safety and Co-ordination Plan.

Thus, where

S_i = safety costs for the i-th operation;
SSS = special safety expenses, determined by means of a suitable calculation measure;
SRP_i= unit safety costs included in the price of the i-th operation, determined by means of a suitable analysis of the prices of individual operations;
SCS = overall safety costs;
IS = mean incidence of the safety cost;
P_i = unit price given in the price table for the i-th operation;
Q_i = amount of the i-th operation needed for the project specification;
C = construction cost: the sum of the prices multiplied by the quantities ($\Sigma_i (P_i \cdot Q_i)$);
U_i = unit profit for the i-th operation;
SG_i = general unit costs for the i-th operation;

IS and of **S_i** are determined in the following way:

$$SCS = \Sigma_i(SRP_i \cdot Q_i) + SSS$$
$$IS = SCS / C$$
$$S_i = (P_i - U_i - SG_i) - [(P_i - U_i - SG_i)/(1+IS)]$$

In other words, in order to determine **IS** we need:

- to determine the portion of those costs which can be found directly by consulting the official price tables and using the quantities specified for the project;

- to determine by calculation the portion of "special" safety costs;
- to add the safety costs that can be found in the price tables to the special costs;
- to divide the resulting sum into the construction cost of the whole project, in order to arrive at the mean incidence of safety costs.

The safety costs shown in the call for tenders do not include either VAT (Value Added Tax) or the Contractor's profit. In particular, since these expenses are not to be bid down, there would be no point in including profits in this process: for profits, by contrast, are an element on which the various tenderers can compete.

In arriving at the **SCS** amount, the Contractor must count every expense and provision needed for full compliance with the overall specifications of the Safety and Co-ordination Plan; in signing the contract, the Contractor will be undertaking to comply fully with every instruction given in the course of the work by the Safety Co-ordinator for the operational phase, or by the Works Manager for the safeguarding of the employees' health and safety.

COST MANAGEMENT

Issues of the handling of safety costs arise in accounting for the works, this being governed by the need to reimburse the safety costs as calculated and set out in the Safety and Co-ordination Plan. With reference to the payment arrangements that may be adopted in the domain of public works (ref. Decision no. 37/2000), the Public Works Supervisory Authority distinguishes four different forms of tendering arrangement:

mixed tendering, with a combination of flat-rate (or fixed-sum) and unit charging;
tendering with flat-rate charging;
tendering with unit charging, where the tendering process is conducted in terms of bids expressed as unit prices;
tendering with unit charging, where the tendering process is conducted in terms of a single discount figure for the whole of a given unit price list .

In the case of mixed tendering, with a combination of flat-rate and unit charging, accounts must be drawn up, for the flat-rate portion of the work and for each broad group of operations within the project regarded as homogeneous, on the basis of the percentages of the price tendered; these percentages must be indicated in the special tender details document and deducted during the actual project from the estimated amount. The portion of the works to be charged by the unit, on the other hand, is accounted for on the basis of the unit prices in the contract. As each stage of progress in the work (**SAL**: stato di avanzamento lavori) is reached, the amount for safety costs will be added to the amount due, in proportion to the work that has been carried out.

Flat-rate tendering is no more than a special case of the foregoing.

In the case of tendering with unit charging, where the tendering process is conducted in terms of bids expressed as unit prices, the work is accounted for on the basis of the unit prices in the contract. In proportion to the amount of work completed, the amount of the safety costs will be added to the amount due corresponding to the state of progress (**SAL**) .

In the case of tendering with unit charging, where the tendering process is conducted in terms of a single discount figure for the whole of a given unit price list, the work is accounted for on the basis of the unit prices for the project. Amounts corresponding to the state of progress are reduced by the discount offered, so that this discount does not diminish the safety costs; the following is the formula used:

$$SAL * (1\text{-}IS) * R,$$

where **SAL** is the amount corresponding to the state of progress, **IS** is the incidence of safety costs on total construction costs and **R** is the discount offered.

No precise regulatory dispositions are available concerning the existence of variations during a project, so that it seems, on the one hand, an acceptable principle that safety costs should be adjusted proportionally, in percentage terms, to increases or decreases in the overall cost of the project; nevertheless it is to be regarded as more correct to recalculate the costs themselves. The nature of the variations could in fact have a decisive influence on the safety costs the Contractor in fact has to face.

In general, however, it is a valid principle that safety costs should be paid to Contractors only as a function of the actual implementation of the prevention and protection measures, preparatory works, &c., prescribed by the Safety and Co-ordination Plan. It is therefore the Safety Co-ordinator's duty at the execution stage to check that the safety measures are being properly applied in the course of the project, and to approve or reject, with reasons, the reimbursement of the safety costs provided for in the Safety and Co-ordination Plan. This approach is also the one taken by the "Safety guidelines for temporary and mobile work sites", issued by the Lombardy Regional government.

These guidelines also suggest a method for the reimbursement of these costs, dividing them into those which have already been taken into account in the estimate of the works (**OD**), which are to be paid, as usual, in proportion to the state of progress of the Works (**SAL**), and particular costs not taken into account in the estimate of the works (**OS**), to be paid as a function of their amount compared with the estimates in the Safety and Co-ordination Plan.

Accounting for the costs at the execution stage, at least so far as concerns the costs not taken into account in the estimate of the works (**OS**), requires frequent on-site attendance by the Safety Co-ordinator at the execution stage. Per-unit accounting, then, while it has the advantage of encouraging and rewarding assiduous compliance by the Contractor with the prescriptions of the Safety and Co-ordination Plan, also has the disadvantage of greatly adding to the burden on the Controller, and moreover distracting his attention from issues more particularly relevant to operational safety co-ordination.

Payment of safety costs on a percentage basis, in relation to the state of progress of the work that has been achieved, remains therefore the most immediate solution that can be applied at the stage of execution. It has another advantage as well. If safety costs are to be accounted for by measuring them, then the Works Manager may find himself forced, still on the basis of the instructions provided by the Safety Co-ordinator at the execution stage, to divide the costs among the various Contractors or Subcontractors who have taken part in the project, as a function of what each of them has in fact done for safety. And yet it is the Contractor's independent duty to distribute the overall amount of safety costs among the Subcontractors (if any) in proportion to the amount of the work corresponding to each of them. The same reasoning can moreover be applied to the case of part tendering where there is no General Contractor, and where Contractor would each be paid an amount proportional to their share in the operation.

CONCLUSIONS

The enactment of an obligation to make a safety cost assessment of a building operation is undoubtedly a step forward, in principle, in civil construction law.
All the same, it must be emphasised that for such an assessment to be realistic it can only be made following the very complete specification of a project. In this sense it would seem to require greater forethought on the part of the Commissioning Party and its technical staff.
The entrepreneurial world, though, must also play its part, through the Chambers of Commerce, in the provision of official price lists in which safety costs are distinguished in advance as a separate part of the prices for each operation; this will provide greater transparency and a more standard basis for assessment of the matter.
The State, for its part, ought to help in bringing some order to the present complex landscape, by issuing the awaited implementing regulations concerning safety plans, as promised in Article 31 of the Framework Act 109 on Public Works, of 1994. The *corpus* of law and regulation will only show itself truly adequate on this matter of safety costs once the total of the safety costs borne by all the individual Commissioning Bodies, properly calculated, is at least matched, in the medium term, by a corresponding decrease in the costs borne by the community. Then, and only then, would it have been effectively demonstrated that attending to safety is one way of making savings.

REFERENCES

[1] Arie Gottfried, Marco Lorenzo Trani – "Il coordinatore per la sicurezza nelle costruzioni in fase di progettazione e di esecuzione" [The Safety Co-ordinator in construction, at the planning and execution stages] – Maggioli Editore, April 2000
[2] Guido Cianciulli – Computo, Contabilità, Costi della Sicurezza, Cronoprogramma e Calcolo dell'Incidenza della Manodopera [Estimating, Accounting, Safety costs, Scheduling, and Calculation of the Incidence of Labour Costs] – Editions Acca, 2000
[3] Veronica Confalonieri, Massimiliano Lanticina – University Thesis in Construction Engineering – "Sulla sicurezza dei procedimenti costruttivi delle strutture orizzontali in calcestruzzo – Confronto in opera di soluzioni tecniche alternative" [On the safety of construction procedures for horizontal structures in concrete – Working comparison between alternative technical solutions] –Milan Polytechnic, Department of Building Engineering and Territorial Systems–Academic Year 1998-1999
[4] Antonello Santini, Umberto Perinetti – Analisi dei prezzi per l'edilizia [Analysis of building prices] – Serie Görlich – Istituto Geografico De Agostini, 1990
[5] Milan Chamber of Commerce, Industry, Crafts and Agriculture – "Prezzi informativi delle opere edili in Milano" Price information on building work in Milan] –April-June Quarter, 2000
[6] Comitato Paritetico Territoriale per la prevenzione infortuni, l'igiene e l'ambiente di Lavoro di Roma e provincia [Regional joint Committee for accident prevention, hygiene and the working environment, Rome and province] – "I costi della sicurezza–

Volume primo – Prontuario per l'individuazione dei costi" [Safety costs – Volume one – Reference manual for identifying costs] – Editions C.S.E. S.r.l., May 1998

[7] Comitato Paritetico Territoriale per la prevenzione infortuni, l'igiene e l'ambiente di Lavoro di Roma e provincia [Regional joint Committee for accident prevention, hygiene and the working environment, Rome and province] – "I costi della sicurezza – Volume second – Preziario per la stima dei costi" [Safety costs – Volume two – Price tables for estimating costs] – Editions C.S.E. S.r.l., May 1998

[8] Legislative Decree 494/1996 dated 14/08/1996 – "Attuazione della direttiva 92/57/Cee concernente le prescrizioni minime di sicurezza e di salute da attuare nei cantieri temporanei o mobili" [Implementation of EEC Directive 92/57/EEC on minimum health and safety regulations to be observed in temporary or mobile work sites]

[9] Legislative Decree 528/1999 dated 19/11/1999 – "Modifiche ed integrazioni al decreto legislativo 14 agosto 1996, n. 494, recante attuazione della direttiva 92/57/CEE in materia di prescrizioni minime di sicurezza e di salute da osservare nei cantieri temporanei o mobili" [Amendments and additions to Legislative Decree 494/1996 dated 14/08/1996 concerning implementation of EEC Directive 92/57/EEC on minimum health and safety regulations to be observed in temporary or mobile work sites]

[10] Act. 109/1994 dated 11/02/1994 – "Legge quadro in materia di lavori pubblici" [Framework Act on Public Works] and subsequent amendments and additions

[11] Presidential Decree 554 dated 21 December 1999 – "Regolamento di attuazione della legge quadro in materia di lavori pubblici 11 febbraio 1994, n. 109, e successive modificazioni" [Regulations implementing the Framework Act 109 on Public Works dated 11 February 1994 and successive amendments]

[12] Autorità per la Vigilanza sui Lavori Pubblici [Public Works Supervisory Authority] – decision 37/2000 dated 26/07/2000 – "Calcolo degli oneri di sicurezza e dell'incidenza della manodopera in attesa del regolamento attuativo" [Calculation of safety costs and labour cost components, pending issue of the implementing regulations]

[13] Public Works Supervisory Authority – Decision 2/2001 dated 10/01/2001 – "Calcolo dei costi di sicurezza nella fase precedente l'entrata in vigore del regolamento di cui all'art. 31 della legge 11 febbraio 1994, n. 109 e successive modificazioni" [Calculation of safety costs prior to the coming into effect of the regulations referred to in Art. 31 of Act 109 on Public Works dated 11 February 1994 and successive amendments"]

A NEW STYLE OF HOUSING BUSINESS IN JAPAN: THE CASE OF A CONSUMERS' COOPERATIVE ASSOCIATION

Kazuya Ohnishi
Dept. of Sciences for Living, Aichi Konan College, Japan
ohnishi@konan.ac.jp

The purpose of this study is to analyze the advanced systems of house supply undertaken by the housing business divisions of Consumers' Cooperative Associations (hereafter referred to as co-ops) in Japan. The Nagoya Citizens Co-op, for example, is one of the most aggressive co-ops in the housing field. It exerts itself to enhance knowledge and skills of the staff. It keeps in contact with reliable architects and contractors. It also holds "seminars on living and housing" for its members. The housing business division of the co-op acts as a coordinator between architects/builders and the co-op members. The estimates the division makes are plain and easy to understand. As for construction materials, it has guidelines related to the health of consumers. It also makes clear and reliable mid-term and final inspections of buildings. This study will clarify the details of the housing business by co-ops in Japan and compare it with that by general (commercial) contractors. The results of this study will show that the housing business by co-ops is definitely consumer-centered from the standpoint of safety and healthfulness of houses.

In recent years housing troubles have rapidly increased in Japan, such as defects owing to harmful construction materials and incomplete construction work. More and more consumers are concerned about safety and healthfulness of houses. These housing troubles are mainly caused by the fact that relations of trust have disappeared between contractors and consumers since houses are not custom-made commodities any more but ready-made ones. Other factors are that few contracts are made for refurbishment work in Japan and that most construction work is not on a large-enough scale for architects to design or manage by themselves. Connecting contractors with consumers, however, is indispensable for making safe and healthy houses. In such circumstances, Consumers' Cooperative Associations, which have developed several kinds of activities for "safety of foods," have set about housing business, stressing the consumers' stance. They act as coordinators between consumers and contractors. The co-ops attempt is expected to set a new standard for housing business in the future.

MATERIALS AND METHODS

Since 1990 more and more co-ops in Japan have entered into the housing business, mainly focusing on refurbishment work in small scale as many housing troubles have become serious such as defective houses and the "sick-house syndrome." At present 53 co-ops (approximately 30% of all co-ops in Japan) are engaged in the housing business. For this study, I focused on the Nagoya Citizens Co-op as it is one of the most aggressive co-ops in this field. The data to be discussed here were collected from the housing business division of the co-op. I analyzed interviews with officers of the co-op to clarify systems of the business.

The Nagoya Citizens Co-op, establishing in 1969, has developed its business mainly for the purpose of supplying safe foods. It consists of about 600 full-time employees and about 1,300 part-time workers. At present approximately 210,000 persons are members of the co-op. The total amount of its business dealings is approximately 37 billion yen (about $333 million <$=\122>). Most of the amount (approximately 35 billion yen – about $287 million) comes from the sales of foods through cooperative stores and cooperative purchasing by its members. The other fields of business the co-op has conducted are mutual insurance, sales/rental of welfare goods, travel agencies, and morticians' services. The co-op started the housing business in 1995. The amount of business at present is about 1 billion yen (about $8 million).

Incidentally, about 600 co-ops are in the union at present, according to a business report by the Japanese Consumers' Co-operative Union. The number of all co-op members is 21 million. That of full-time employees total about 56,000. The total amount of business dealings by all co-ops is 3.32 trillion yen (about $27 billion). These figures suggest that co-ops have the potential to improve the present problematic house-supplying business.

RESULTS

Outline of the Housing Business by the Nagoya Citizens Co-op

Conceptions of the Housing Business

The Nagoya Citizens Co-op has developed a housing business according to the following three conceptions.

1) To deal with construction on any scale from partial refurbishment to full construction of houses in cooperation with reliable specialists in this field
2) To exert itself to make healthy, barrier-free houses in consideration of the natural environment
3) To collect and introduce information and ideas about safe construction materials and for comfortable lives

Contents of the Housing Business

The details of the business by the co-op are as follows.

1) Consultation on housing: architects and contractors give advice to the co-op members in local centers.
2) Diagnoses of houses: architects inspect members' houses at some charge, pointing out where repairs should be made and making estimates of the costs.
3) Small repairs: repairs of roofs, exterior walls, and gutters; changes of *fusuma* (paper of Japanese doors and of doors of Japanese closets) and of *tatami* (Japanese mats); installation of handrails; and trimming of trees in gardens
4) Refurbishment work: installation of new equipment in kitchens, lavatories, and bathrooms; and extensions for children's rooms
5) Full construction of houses: the co-op proposes a new construction style with the collaboration of architects as partners.

Number of Cases with which the Housing Business Division Deals per Year

Here is the breakdown of the cases the housing business division handles annually.

1) Consultation on housing: approx. 3,000 cases
2) Diagnoses of houses: approx.50 cases
3) Small repairs: approx. 200 cases
(the average construction charge: 80,000 yen <$660>/case)
4) Refurbishment work: approx. 650 cases
(the average construction charge: 650,000 yen <$5,330>/case)
5) Full construction of houses: approx. 20 cases
(the average construction charge: 28 million yen <$230,000>/case)

In addition, the division deals with approximately 1,000 cases in the category of "other." These account for about one third of all cases of consultation.

Unique Systems of the Housing Business Division

The housing business of the Nagoya Citizens Co-op is featured by the following :

1) Collaborating contractors' club
2) Collaborative project by architects
3) Seminars on living and housing
4) Information station / consulting sessions on housing
5) Guidelines for clear and easy-to-understand estimates
6) Inspections with customers (mid-term and final inspections of houses)

Process of the Housing Business

The housing business by the co-op is conducted under the following process.
(*The following 6 – 8 are the process only for refurbishment and full construction work.)

1) The co-op makes contracts with architects/contractors to establish collaborative relationship.
2) It distributes leaflets to the members (announcing to consulting sessions).
3) It receives members' requests for consultation with specialists.
4) Architects give advice, conduct inspections, and propose appropriate plans and estimates for the members.
5) The members entrust construction (including repairs) to contractors.
6) The consulting architects start designing. (They show drawings and estimates to the members.)
7) Construction work starts after the members make contracts with contractors.
8) The co-op and architects make mid-term and final inspections from the viewpoint of the members.
9) Contractors turn in a report to the co-op after the work is completed.
10) Contractors charge the members for the construction.
11) Contractors pay charges to the co-op for the clerical work and turn in a report to explain the progress of the work.
12) The co-op offers after-sales service to the members.

Characteristics of the Housing Business conducted by the Nagoya Citizens Co-op

Collaborating Contractors' Club

The housing business division of the Nagoya Citizens Co-op collaborates with reliable contractors (approximately 20 companies so far) to maintain high standard of construction.

The division makes contracts of collaboration only with the contractors who understand the co-op's policies for its housing business and undertake to follow the principles and rules. The contractors are also obliged to join the collaborating contractors' club. This is a "mutual-aid" organization for the improvement of their skills and for sound management. Such an activity is expected to increase the co-op members' trust. The meeting is held once a month to cope with troubles concerning the housing business, to train supervisors on construction sites, and to fix the club's rules. The club also has its own manual of manners on construction sites (e.g. regarding greetings and clean up). The manual helps enhance the co-op members' confidence in the contractors. At the consulting sessions by the co-op the contractors give useful free advice as specialists to the co-op members. The partners of the division to form a collaborative network are not big construction companies but comparatively small local ones. The co-op intends to develop local companies as well as to supply the co-op members with houses of high quality.

Collaborative Project by Architects

This project, supported by the Nagoya Citizens Co-op, was initiated to examine any issues on the living environment and to propose concrete solutions. By making the flow of construction work systematic and by standardizing it as much as possible, architects expect to supply the co-op members with houses of high standard quality. They also try to demonstrate the basic policies of "the Co-op housing" to the members. Approximately 20 design offices have joined the project so far, conducting several activities such as "Studies of Co-op Housing," "Studies of Construction Materials," and " Studies of Construction Methods and Costs." In "Studies of Co-op Housing," they study the basic ideas of what Co-op housing should be like. In "Studies of Construction Materials," they search out or develop materials which are safe for the health for use on construction sites. In "studies of construction methods and costs," they develop and standardize proper construction methods to stabilize the construction costs. At the consulting sessions by the co-op the architects also give free useful advice as specialists to the co-op members.

Seminars on Living and Housing

Seminars led by the co-op members are held about once a month. The topics so far have been "Self-support of the Elderly and Housing," "Health and Housing," "A Field Trip to see Domestic and Imported Construction Materials," and "A Field Trip to see Houses Built by Co-ops."

Once the members visited an exhibition of general house suppliers and evaluated the houses by workshop method in consideration of the conceptions on housing proposed in their seminars (e.g. constructional safety, healthy and organized life, harmony with surroundings, and energy saving). Before and after the workshop the members filled out a questionnaire about what is required for houses. The result was that "secure structure of foundations," "suitability for the climate of Japan," and "no harmful materials to be used" were the responses most frequently cited after the workshop, while "places for family to chat together," "proper storage (space and position)," "and "easiness of cleaning" occupied high ranks before the workshop. It shows that the points to weigh with them changed from "space" to "safety and health."

Information Station

The housing business division of the co-op constructed an "information station on housing" with collaborating contractors to let the members experience comfortable living space. It consists of varied rooms and space as follows.

1) Kitchen: customers can cook here to check its convenience. Cooking classes are also held here.
2) Space in Japanese style (with organic *tatami*): customers can realize the coziness of Japanese rooms.
3) Space with equipment for those who use wheelchairs: slopes
4) Space with barrier-free design: a chance to experience the difficulties with steps.
5) Exhibition corner of construction materials: materials can be tested by touch.
6) Consultation corner
7) Multi-purpose room can be used for study sessions on housing.

In contrast to general showrooms where the staff introduce their houses and equipment one-sidedly and try to start negotiations, visitors here can experience rooms and space along themes and meet and talk with specialists whenever they want to.

Guidelines for Clear and Easy-to-understand Estimates

Construction materials are estimated on the basis of "Guidelines on Construction Materials for Health." Materials should be classified as follows according to the guidelines.

1) Wall Paper: Japanese paper / cloth / vinyl chloride
2) Glue for Wall Paper: with or without formaldehyde; natural / synthetic resins
3) Wooden Flooring: natural wood / plywood (as graded by the JAS (Japan Agricultural Standard))
4) Sheet / Tiled Flooring: natural (e.g. cork) / vinyl chloride
5) Glue for Sheet / Tiled Flooring: natural / synthetic resins
6) Plywood: as graded by the JAS
7) Paint: natural / synthetic resins
8) *Tatami*: with or without solvents to keep insects off; with or without coloring on the surface; rushes (of which *tatami* is made) - organic / imported

As for "1. Wall Paper" and "3. Wooden Flooring," they are classified into three levels so that the members can make their choices by themselves: the materials on level 1 contain few chemical substances; those on level 2 are much closer to natural ones; and those on level 3 are purely natural.

Inspections with Customers (Mid-term and Final Inspections of Houses)

"Inspections with customers" is a system for the solution of claims and complaints from customers. Though these inspections are essentially the "self-responsibility" of contractors and architects and "spontaneous checkups" by them, the co-op arranges the principles on the basis of the amount of contracts in the following way. (1) In the case of construction in the amount of less than one million yen ($8,200), mid-term inspections are made by contractors alone and final inspections by contractors in the presence of the co-op members (customers). (2) In case with amounts of one million yen or more but less than five million yen ($41,000), both inspections are made not only by contractors but also by the housing business division of the co-op. (3) In case with amounts of five million yen or more, both inspections are made by contractors, together with architects and the division, in the presence of the members.

Any inspections are conducted according to the checklists prepared separately for contractors and the co-op housing business division. At mid-term inspections by contractors approximately 150 items are checked on foundation work, carpentry, floors, walls, ceilings, electrical equipment, and plumbing. At final inspections, the contractors check approximately 70 items on roofs, exterior walls, windows, exteriors, and interiors (floors, walls, ceilings, and doors). As for the items to be checked by the division, it checks the degrees of the customers' (members') satisfaction from diverse angles as follows.

- Contractors' attitude towards customers

9) behavior and manner of speaking
10) explanation on the construction to be conducted
11) observance of schedule
12) prompt reporting / observance of promises

- Contractors' management and the quality of their work

13) safety on construction sites
14) cleanup after the construction is completed
15) consideration of noise during construction
16) completeness of the work

- Charges for the construction

17) explanation on the details and the cost of the construction
18) explanation on the details and the cost of additional work

OTHER CONSIDERATIONS

The increase of defective houses in Japan derives from the following factors. (Ohnishi and Ueno, 1999) [1]

1) Treatment of houses as ready-made commodities
2) Excessive rise of the price of land
3) Multi-tiered structure of subcontracting
4) The system in which one company undertakes the whole work of design and construction
5) Lack of know-how of carpenters
6) Inspection systems by public administration

In addition the major causes of troubles with refurbishment work by general (commercial) contractors are:

1) one-sided explanations for their profit when consulted;
2) obscure estimates;
3) no written contracts but verbal ones made in the cases of construction on a small scale;
4) construction materials inexpensive but of poor quality instead of safe ones (no concern for health and safety);
5) careless and incomplete work by carpenters and craftsmen on site due to a multi-tiered structure of subcontracting; and
6) no faithful reactions to troubles and problems found after construction work is completed. (Ohnishi, 2001) [2]

Another issue is the business styles of general house suppliers. A research project involving big and local middle-class house suppliers reveals that all of 28 companies which cooperated for the research have some of the following problems. [3]

1) Insufficient drawings attached to contracts (e.g. they only attach some of specifications, drawings of arrangement, or two-dimensional and three-dimensional drawings)
2) No detailed estimates (no specific mention of specifications and quantities)
3) No detailed plans of working process
4) No documents for entrusting design and management to the companies
5) Insufficient drawings of construction / No drawings of completed buildings

As for the construction cost of newly built houses, some house suppliers sell houses at such low prices as 300 thousand yen ($2,460) or lower per floor space of 3.3 square meters. The fact, however, is that consumers have to pay for additional construction work since the prices do not include much necessary work such as installation of equipment and since the quality of the materials used at those prices is of the lowest grade. After making contracts, consumers find themselves paying twice as much as the basic price since the suppliers require them to add necessary equipment. The point at issue is that consumers have no choice but to decide on housing plans based on the price per floor space of 3.3 square meters, without examining the specifications concretely.

Judging from the results of the research for this study, it is clear that the Nagoya Citizen Co-op solves the problems which general house suppliers have with their unique systems as stated before. That is, the co-op's policies are:

1) not only to make consultation / explanations for the standpoint of the members but also to give information on or hold seminars on house-building for the members;
2) not only to make clear and easy-to-understand estimates according to the guidelines but also to explain them in detail;
3) to take the responsibility for contracts even though the construction work is done by collaborating contractors;
4) to supply the members with safe and healthful construction materials inexpensively, as a result of cooperative purchasing;
5) to introduce reliable contractors through the systems of the collaborating contractors' club and the collaborative project by architects and to make mid-term and final inspections securely through the system of "inspections with customers"; and
6) to provide periodical maintenance. (Ohnishi, 2001) [2]

CONCLUSION

As stated before, the housing business of co-ops features by their endeavors to keep safety and health from the standpoint of consumers. The most outstanding characteristic, however, is that in their systems consumers can learn what "good life" is through their deliberation on housing. The roles of the housing business of co-ops in Japan are to help people live healthy and cultivated lives as well as to increase the number of houses of high quality through their full construction of houses or even through their refurbishment work.

Since 1960 houses in Japan have overflowed with industrial products due to high economic growth. People have consumed and discarded these products one after another. In Japan consumers have been hardly educated especially on living and housing. People started to get concerned with housing issues as mass media have recently picked up such topics as defective houses and the sick-house syndrome; yet the world still overflows with one-sided information to help house suppliers sell their commodities. People cannot get necessary information on refurbishment and full construction of houses as there are few organizations that are reliable sources of the information in Japan.

The Nagoya Citizens Co-op has systems in which all of the co-op members, the co-op staff, architects, and contractors can learn about housing. In the systems architects and contractors not only improve their skills and knowledge but also learn so that they can make appropriate proposals to each member, thinking over housing from the viewpoint of "living." The co-op members hold seminars to study about housing from diversified angles. The co-op exchanges information with the other co-ops. As for the housing business, the co-ops engaged in the business meet together once a year. In addition, the Nagoya Citizens Co-op locally exchanges information with several NPO's such as associations of forestry, groups to study garbage and recycling, and those to study allergies.

Unfortunately many co-ops have not entered into the housing business yet since the scale of the business is supposed to be small. Why the scale is so small is that only 20% of all co-op members know about the co-ops' involvement in the housing business. They still think that co-ops are engaged only in the business of food sales. Enhancing the members' recognition of the co-ops' housing business is indispensable to make the co-ops' systems enter the mainstream of housing-supply business in Japan.

ACKNOWLEDGMENTS

I am grateful to Mr. Shinji Isobe of the Nagoya Citizens Co-op for his assistance with this study and to Professor Katsuyo Ueno for giving me valuable advice.

This study is conducted with subsidies for scientific studies from the Ministry of Education in 1999 and 2000.

REFERENCES

[1] Ohnishi, K. and Ueno, K., (1999), "The Mechanism of the Occurrence of Defective Housing in Japan," *Implementation of Safety and Health on Construction Sites*, pp.139-45, U.S.A.

[2] Ohnishi, K., (2001), "Study on the Housing Business Operation by Consumers' Life-Cooperative Association in Japan," *Creative Systems in Structural and Construction Engineering*, pp.63-68, U.S.A.

[3] The Designers' Association against Defective Housing (ed.), (2001), *House Maker Jutaku Shindan < Diagnoses of Houses built by Housing Suppliers>*, Kenchiku Journal Sha, Japan.

QUALITY MANAGEMENT IMPLEMENTATION IN CONSTRUCTION PROCESSES: A CASE STUDY IN QUALITY MANAGING FOR ROOFING OF COMMERCIAL BUILDINGS

S. Mecca, M. Masera
Dipartimento di Ingegneria Civile, Università degli Studi di Pisa, Italy
lucat@laerte.penteres.it

The aim of quality management is to identify an activity performance level or a grade of client satisfaction and improve them through failure risk, damage or performance loss.

Risk management represents a strategic dimension of quality management methodology in order to plan more reliable and efficient processes. The first experiences of developing quality systems in construction firms and of implementing quality plans in construction processes are showing that the specific uncertainty conditions of site require a wider and more effective management approach than a formal ISO approach. The aim can be therefore to relate the environmental, organisational and technical factors affecting production processes in order to define a more effective quality plan.

A case study of a specific quality plan for flat roofing in a commercial centre is presented . Based on a scheme of integrated project and quality management tools, the aims were to provide a systematic approach to prevention and correction of non-conformance critical conditions. A FMEA-style risk analysis supported quality management for determining the appropriate prevention measures in tender, operative planning and in construction phases, in order to contribute to obtaining reduction of failures and higher efficiency levels.

Keywords: Quality Planning, Technical Risk Analysis, Concurrent Enginnering

INTRODUCTION

The theory for the development of a total quality model for the building industry requires careful consideration of actual conditions in building planning and construction processes with particular reference to organizational aspects of the work. In this area there are two quality management development frontiers which should be developed:

- the first requires the combination of business quality systems with planning production logic; we think we will be able to achieve this result by applying risk analysis methods which will allow us to manage planning and construction processes.
- the second requires the introduction of quality management systems in working conditions implicitly or explicitly typical of concurrent engineering conditions.

Project and/or contractual failure, that is, organisational failure and functional failure, that is, technical failure are strongly connected in any risk analysis perspective. Organisational factors weigh on the likelihood of technical faults: a subcontractor dissatisfied either with the contract, or time factor, can neglect quality and safety. Failure in planning or in cost-estimating can produce specific and general risks. An inadequate project definition, the lack of clear objectives and the lack of communication about problems, create the conditions for high risk impact in developing an activity. Some failure characteristics do not affect the finished product, however, they play an important role in the face of technical risk.

THE RESEARCH GOAL

Research goals involve the development of the approach to quality management of a job which considers the actual conditions of the state of grading of the project and suppliers. Starting with these, they could introduce an improvement process in the light of three converging goals:

- to fix the instruments for a concurrent project management both on the basis of collaborative integration of decisions made by different partners, and on the basis of integration between planning and construction phases which are getting more and more coincidental, and with continual feedback and adjustments which continually change the results of the project;
- to improve building and planning grading procedures, prompting continual improvements in an area where the threshold of purchasing certification is kept very low and without initially changing existing business procedures.
- to use risk analysis of construction techniques as an instrument to define quality management procedures in the context of planning production.

INRES, the Association of Engineers, has become interested in these goals and would be willing to set up an experimental project for which a collaboration protocol has been defined.
The INRES corporate, owned by the UNICOOP group, is one of the greater Italian engineering company specialised in the project management of commercial centres.
INRES specializes in the making of a specific building system, a market unrelated to public work contracts. They have made some useful premises to define a research area limited by, and very typical of, concurrent engineering processes in the development of the project.
The quality management procedure prepared for the INRES considers the specification, beside the formation of the personnel, of establishing a Quality Plan for each project.
For each operation the site director, at the end of the preparation period that follows the closure of the contract, presents to the off site management the general technical and financial plan of the operation. A plan of quality assurance is associated to the global plan.
The case present the main documents of a specific quality plan for the realisation of the new commercial centre called "Le Piagge", in the province of Florence, consistent in the construction of a 3 storeys building, with a parking in the basement.
The strategy of quality management adopted by INRES was based mainly on a risk analysis tecnique that supports the action of prevention and control.

IMPROVING THE QUALITY PLANNING THROUGH A FMEA APPROACH

Failure Mode and Effects Analysis is an analytical technique that can support decision-making and quality planning in different planning and management phases of the project (Mecca and Masera 1999, Stamatis 1995). FMEA aims at foreseeing the non-conformity of the building and of supplying information for an effective quality management of the project. Its application to building constructions requires a careful conceptual development of the tool that makes it adaptable to the kind of information to be dealt with.
The typical phases of the FMEA for industrial processes are:

- identification of the error modalities, the faults, the non-conformities and investigate the cause and effects relationships for them;
- identification of a risks index on the basis of error probability, severity and visibility;
- provide adequate measures for risk treatment.
- The FMEA is effective if it manages to deal with available information and to produce reliable evaluations. In the field of building constructions the challenge of correct information management is crucial because:
- risk dependence on numerous factors makes both a quantitative measurement and a qualitative evaluation difficult;
- factors vary notably from project to project and their contribution in cause determination is uncertain;
- risk assessment requires subjective judgement by an expert and is the result of great experience.

Unlike qualitative approaches that carry out risk ranking following fixed and generic evaluation schemes of probability, severity and non-detection, an FMEA for buildings needs the definition of:

- risk factors and conditions that explicitly and specifically produce failure owing to examined technological processes;
- objective and verifiable criteria;
- criteria in which the specific causes and effects of failure are recognised;
- a lower number of risk categories for every risk condition.

Satisfying these requirements allows the improvement in typical evaluation of the FMEA that works with synthetic numerical judgements/evaluations. In the absence of reliable measurements the judgement does not point out the choice criterion that supported the decision and does not supply indications for appropriate prevention and corrective actions.
The aim of an FMEA suitable to building construction is to make plain the knowledge base from which the expert draws to assess a specific risk and that justifies the decision-making process according to the principles of Total Quality Management.

EXPERIMENT DEVELOPMENT

The used methodology consists of an approach that evaluates the non quality risk of the project parts, or subsystem. This approach aimed at identifying the critical degree of the project/process parts and classifying them. Two steps of analysis were considered: one level

for adapting the assessment model with criterion definition and a second level of the specific data of the project examined.
The first step required to analyse the project organisation aiming at identifying the major wastes affecting the construction processes:

- the workpackages are listed and analysed;
- a risk level attribution is given for ranging the more critical processes.

For this purpose the data resulting from the contract document were utilised. Furthermore technical literature on building pathology are screened for the risk assessing process. From the analysis results a hierarchy of criticality of the production processes.
The identification of the experimental domain is made of two analysis steps that are developed as follows:

- The first step of analysis identifies the work packages to be analysed and develops the determination of a criticality index for sub system or part of a project. The parts of the project to be analysed are identified through a WBS technique as showed in Table I.
- The second step considered the evaluation of the project portfolio of the company for identifying the experimental domain. The evaluation techniques required:
- criterion for project grading (or part of project, or component);
- correlation between the score assigned (sum or product of each evaluation);
- correlation between the criticality level and consequent prevention action and level of control to be activated.

Table I: WBS of the general project of the commercial centre.

Site preparation	**Structural work**	**External envelopment**	**Roof work**	**Thermal Comfort**	**Acoustical Comfort**	**Facilities**	**Safety systems**
Excavation	Grading	Envelopment	Roof	Envelopment	Envelopment	Gas net	Fire protection
Grading	Piled foundation	Facade	Roof glazing	Roofs and lodges	Roofs	Electrical net	Fire alarm system
Accesses	Deep basement	Cladding	Chimney stack	Interface with non heated locals	Doors and windows	Phone net	Electrical safety net
Boundaries	Foundation	Glazing	Water tightness	Ventilation	Interfaces between locals with different function	Internal frames	Sprinkler
External works	Structures	Metal Frames	Water piping	HVAC facilities	Suspended floors	Lifts	Water safety net
Water points	Metal Frames	Air captation	Insulation		Lifts		
	Stairs, Structural joints, Precast components	Insulation					

Risk level assessment

For this case the levels of criticality relative to the elements of the subsystem are determined using three criteria. Each criterion score from 1 to 3 points the criticality. By adding the three criteria is obtained the level of risk for the critical point. After the decomposition of the project in systems to be analysed, determined the criteria of analysis, and the scale of the score to be assigned, it results a hierarchy of evaluated elements as generalised in the Table II.

Table II: Work element classification

Criterion of analysis of the work elements				
Work Element examined	**Complexity level** Score	**Aptitude to failure** Score	**Importance level** Score	**Total** (Criticality Index Ic of the element)
Element 1	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$3 \leq Ic \leq 9$
Element 2	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$3 \leq Ic \leq 9$
Element ..	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$3 \leq Ic \leq 9$
Element n	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$1 \leq p \leq 3$	$3 \leq Ic \leq 9$

The scores assigned to the three criteria are referred to the following concepts:
Level of complexity

- Complicate technical study: complex calculation or innovative solutions;
- many specific cases for the same type of construction;
- models or mock up are required; many interfaces between the construction elements.
- Carefully assembling: tolerance, complex forms or geometry, particular finishing, special tools required, reliability of repetitive action, difficult control.
- Not usual characters of the project: not traditional component; not usual specification for the components.
- Aptitude to failure
- Specification extra standard: aspects of finishing, specification of use and maintenance, tolerance and so on
- Historical data: case observation, non quality cost record, maintenance issues.
- Level of importance
- Importance of use: aesthetic aspects, functionality in relation to other components, cost effects of failure.
- Importance of safety for user: fire safety; plant protection.

The index of criticality of each element of the project is correlated with a given level of criticality. The subsystem which has the highest level of criticality for project characteristics, for the consequences in terms of costs and damage to other parts of the building, and in relation to the evidence of such consequences, is the roofing system.Usually this system is a flat roof with different performances relating to practicable roofing, the layout of technical levels on which to place ventilation systems, heating and refrigeration of cold stores. The range of different performances is often within a single project.
In the second step of analysis the experimental program required the identification of an applicative case which met important criteria relating to the area of flat roofing and significant ones concerning PDCA experimentation which it intended to carry out.

a) score allocation: the process or the part of process is identified and the category of analysis are extended. Furthermore the scale of assessing risk is established and criticality index results as showed in Table III.

Table III: Criticality index determination

Technical system (or sub) X	
N analysis criterion	Score of risk (*)
Category 1	$1 \leq P_1 \leq n$
Category 2	$1 \leq P_2 \leq n$
......	......
Category N	$1 \leq P_N \leq n$
Total Criticality Index (Ic)	$N \leq Ic \leq nxN$

b) Classification of the process and the parts of the process.
The index of criticality of the process or its part, obtained adding the score of each categories, is related to a determined level of criticality of the project. Next the general prevention measures can be adopted or a particular configuration of the plan can be defined. The Classification of the project systems or subsystems
Five levels of criticality are established. Each level has a score variable from 1 to 3 points. By adding the six scores results the total criticality as showed in Table IV.

Table IV: Criticality Index determination

5 Criterion of analysis	**Score**
Level of technical complexity related to the building characteristics	$1 \leq p \leq 3$
Level of technical complexity related to the site characteristics	$1 \leq p \leq 3$
Level of requirement	$1 \leq p \leq 3$
Relevance of the **construction cost**	$1 \leq p \leq 3$
Relevance of the **construction milestone**	$1 \leq p \leq 3$
Total (Criticality Index Ic)	$6 \leq Ic \leq 15$

Each category of analysis is assessed starting from a list of a point to be considered as possible element of risk:

- Level of technical complexity (conception and execution): Complicate form; extraordinary structure; special techniques of assembling; extraordinary dimensions; particular case; difficulties connected to the site or to the geological parameters, functions that has to be active during the construction phases.
- Level of requirement: particular requirements, particular functions; particular reliability of the performances; high intensity of use.

- Costs and time: financial level of the project; high cost of production; high cost of equipment; short time of production.

TECHNICAL RISK ANALYSIS FOR ROOFING OPERATION

The case examines the quality planning of a flat roofing operation. The purpose of the study is to identify the critical point of the project and to grade them by mean a Failure Mode Effects Analysis (FMEA) technique specified for the following objectives:

- To forecast the non conformity of the construction and to provide the information for an efficacy quality management;
- To trace the decision process aiming at risk study and prevention.
- The FMEA phases defined for the quality planning were:
- To identify the error mode, the defects, the non conformity and analyse the relation of cause and effect;
- To identify a risk index based on the probability, the severity and the failure detectability:
- To plan adequate measure for the risk treatment.
- The application of the management technique regarded several project steps:
- Design phase; the FMEA was finalised to the improvement of the technical solution;
- Bid phase; the FMEA was finalised to evaluate the global risk connected to the contract, and to specify the contract clauses that forces the contractors in a quality management scheme;
- Quality planning stage; the FMEA was finalised to the critical points identification, and define the subcontractor performance;
- Production phase; the FMEA was finalised to monitor the quality plan management.

The requirements of efficacy for the technique require the risk are not classified in rigid and generic schemas and that the evaluation is reliable about the probability, the severity, and the detectability by mean:

- The clear identification of the risk factors and the risk condition that produce a failure;
- The definition of criteria objective and verifiable;
- The definition of criteria that synthesises the specific cause and the effects of a failure;
- The definition of few risk class for every risk condition.

APPLICATION OF A FMEA TO THE ROOFING SYSTEM

The application of FMEA to the construction management requires a substantial methodological innovation respect both quantitative and qualitative approaches.
The innovation introduced results from a qualitative approach that requires a careful specification of risk conditions and effects in construction process, and that requires a validation of the evaluation criterions.

Some tests are directed to provide the knowledge base and procedures for quality and risk management in design, tender and construction activities to the engineering company.

In design phase the FMEA proves to be a valid support to improving quality management, by cycling risk analysis and assessment in order to choice the best technical solution at reducing increasingly the risk rating.

In the tender phase the FMEA is applied as support for the specification of the quality management requirements. In a performance perspective the contractors are required to provide an adequately graded quality plan to assure the technical risk control relative to the quality of performance.

In planning and in realisation phase, a the FMEA methodology for building construction has been obtained to assist contractors in quality planning.

Planning documents substantially are derived from a collaborative risk analysis adapted to the customer's requirements and to the complexity of the activities, graded in relation to failure risks. The main functions of quality plan prevention, control and non-conformity treatment are concentrated on the critical events.

A PROCEDURAL SCHEME OF TECHNICAL RISK MANAGEMENT IN CONCURRENT PROCESS

Aiming at knowing the risk of the project is posed the problem of having at disposal a frame of the technical pathologies, of potential failure deriving from production and management. The need of supporting the design decision and the management decision in each project phase is considered. The key actions developed are:

- The design review and the construction process review;
- Diagnostic of the principle pathologies of the process
- Risk analysis
- Establish the risk treatment

The tools applied are represented in the Table V.

Table V: stages and tools of Technical Risk Management

Stages	Tools		
Process and design review,	Functional Analysis	Wbs, Obs, Pbs	IDEF0 diagrams
Diagnosis of building construction pathologies	Interface Analysis	Cause And Effects Diagram	Fault Tree
Risk analysis	risk factors analysis	Risk Condition analysis	Risk evaluation
Risk treatment	Risk support to decision	Risk support to prevention	Risk support to control

Design review and process review

The preparatory action aimed at identifying the parts of the system and the construction activities that can be interested from failures. The revision of the production process permits to explicate the performances and the specification of the object that has to be built. The functional analysis helped in defining a hierarchy of the function of the technological subsystem. Therefore the domains of failures were circumscribed.
The performances of the technological subsystem are evaluated as performances of the production process, condition of process failure, and of the finished product either as loss of performance either as percentage of cost for the object maintenance.
WBS OBS PBS classification. Through WBS are obtained the classification of the construction components, activities, and construction partners. The project analysis was oriented to the performance of the system, classified on different detail level.
Flow chart of the process. From the basic information of the WBS the activities are ordered in a flow chart based on a logical-technical criterion and explicating the condition of operability and the characters of the partial products.

Analysis of the Diagnostic on the Technological System

The potential failures are classified through an analysis of the technical literature on to level:

- an initial recurring fault and possible non-conformity analysis phase through the data bases. Diagnosis of the pathological processes permits description of the effects of deviation from the required conditions and performance losses that can result from them;
- a successive phase pertinent to the project to carefully evaluate the lack of information in studies and documents related to the performance activity required. The gap between poor information conditions and an expected activity performances is considered as a pathological condition to be prevented.

Observation of Case Study. WBS of the Potential Defects

The results are specific check list of failure mode for the on going project. The objective is support a FMEA analysis on different detail level. The potential failure are associated either to components, either to parts of components.
The classification of the failure results from a grid of performance that characterises the technological system and is articulated on three levels that identifies:

- the defects and the anomalies of the materials and components;
- the defects and the pathologies of the production system in every project stage and deriving from the organisational interface.
- the defects of the assembled component in situ, technical interfaces, and so on.

Example of component failure regarding the organisational interfaces in the design and in the planning phases is the lack of coordination between the designer, the absence of a specific technical level of system design, are common source of numerous technical risks. Particularly exposed to risk are the following aspects:

- The briefing of the project
- The concurrent planning between the main contractor and the sub contractors.

Risk factor analysis.

The passage from the analysis of failure modes to the analysis of technical risk requires the transformation of knowledge of the technological system pathologies into conditions of specific risk for the construction to be achieved under examination in a determined phase of the project management. The key for a systematic consideration of each individual risk consists of guiding the analysis by means of risk factor grids.
The following high level categories of risk factors are examined:

- Technical risk factors;
- Organisational risk factors;
- Environmental risk factors.

In an FMEA for constructions it is also necessary to consider, besides the technical conditions of the fault, the environmental and organisational conditions whose possible effects should be foreseen for effective project management. The effectiveness of the activity of project management, the relationships among firms, are sources of risk of non-quality that may have a decisive impact on the technical quality of the construction. In a systematic approach, every organisational company level is involved to perform risk analysis. In the same way the environmental risk factors related to the environmental conditions where work is carried out are highly relevant. Such factors as geographic, regulations-standards and social-economic factors need to be examined. Each of these may contain further specific factors. Organisational risk factors are produced by the organisation necessary for project execution.

The risk factor grid guides the definition of the evaluation criteria for each factor intended for consideration. Comparing the traditional qualitative approaches that, in the absence of reliable probabilistic data, fall back on the schematisation of subjective evaluation, risk analysts are asked to specify the criteria used to evaluate the individual factors. Validation of the risk evaluation procedure is based on requirements such as the objective and clear identification of the risk categories and their capacity to synthesise the significance of the causes and conditions. For each risk component, occurrence, severity and detection the specific environmental, technical and organisational risk factors are identified and the risk conditions are defined and the relative risk categories that enable an evaluation to be made.

Risk evaluation.

The risk index comes from the multiplication of the probability, severity and detection factors for each critical point. The Probability Rating, Severity Rating, Detection rating, are distinct sums of the risk conditions recorded for each factor.
The occurrence factor comes from the evaluation of the individual risk conditions that totalled allow a probability index to be established for the risk under examination. Instead of favouring the statistical recording of data usually only slightly homogeneous and affected by considerable conditioning, the definition of risk conditions in turn enables definition of conventional indices on the basis of observations carried out on cases that offer analogous conditions to those of the project for which the criticality should be established.
Risk severity ranking allows the entity of the risk to be established and its impact on things and people. Evaluations about quality loss, additional costs, or the lengthening of time required can be identified for every participant in the project, buyer, firm user etc.

Non-visibility expresses an index of the timeliness with which a failure mode can be recorded, measured and treated. It is a crucial risk component for process quality management, because the possibility of preventing and acting upon non-conformities depends on it. The greater risk is evaluated with respect to non-visibility, that tends with time to exclude an effective treatment of non-conformities, as well as to increase the cost of repairs, to make ascription of responsibility more difficult and to make the effects of the failure mode weigh on the final user.

Risk treatment.

The risk indices assumed as absolute values or fractions of the maximum indices obtainable are the basis for the classification of the risk analysed. The interpretation of the obtained index varies in relation to the expected function.
The actions that are generally taken are aimed at diminishing probability, limiting the severity of impact and at increasing the ability to detect failure. Other actions have the effect of clearly attributing responsibility to whoever has the greater competence to take the risk. All the actions of the organisational project can be affected by a risk evaluation corresponding to alternative. Design can be supported by means of analysis repetition according to the modifications introduced, from which risk levels emerge that are then compared to obtain a progressive risk reduction.

A CONCURRENT MANAGEMENT OF QUALITY PLAN

The quality plan preparation considers the formal steps for arranging the organisational structure of the project. The principle partners involved are:

- the purchasing INRES office;
- the off site INRES director;
- the INRES on site management;
- the sub contractor PROTECNO charged of supplying material and of managing the realisation;
- the ETRURIA Corporate as main contractor charged of coordinating the quality plans

Preliminary work relating to the orchestration of the building program involved the compilation of a program relating to the identification of the roles of all partners in the process. This was to establish available manpower to carry out work and checks, and to organize internal control operations, or within the structure of each partner, and external checks, or to check project development by INRES with the help of external auditors from the University of Pisa
The analysis of organizational risks has shown the importance of co-ordinating the interfaces between implementing partners. In cooperative analysis of technical solution particular care was posed on the following interfaces:

- between the builder of the concrete frame and the water protection membrane
- between the builder water protection membrane realisation and the openings on the roof
- between the water protection membrane realisation and the facilities installation

The control plan examined the main parts of the implementation process in the flat roofing work package. It took into consideration not only the checking of implementation phases but also the storage of materials on the building site and the protection of work undertaken before delivery to the client and possible processing of non-conformities. Firstly, the storing areas of materials are identified on a drawing to be annexed. Other annex described the general condition of storage and maintenance, and the frequency of control in the storage area. For the material transport the dimension of the lorry, the download area, the maximal weight admissible are described. Each sub contractor is responsible of storing, maintaining, and cleaning up all under his competence.Specific documents describes the modality of storing (vertical, horizonta and so on) and of different materials and products. Some documents relative the protection measure used for the control of the specification are arranged. The documents for the non conformity management are redacted when a non conformity is observed.

SIGNIFICANT ASPECTS OF QUALITY PLANNING

The diagnosis of malfunctioning and a careful analysis of the risks has enabled the working out of a systematic approach to the prevention of non quality by means of three basic steps:

- the establishment of a control model to be applied at the planning stage to systematically prevent errors in planning or simple ommissions which affect the management of building site information;
- management of the contract stage by means of a series of restrictions which may precede an orchestrative phase of the quality project;
- a phase of building site preparation and implementation management by means of a quality dossier which summarizes both planning errors and construction detailing decisions and aspects of quality planning in the strict sense of preventative measures and checks applied at different stages in the project.

The grading of the detailing design started with the checking of draft plans for which suitable checklists were developed for checking both the completeness of the list of draft plans and the completeness of single tables relating to information shown.
The control procedure checked individual jobs and resolved project problems by co-ordinating the development activities of building details.

The orchestration of preventative measures was given particular attention with regard to the technical interface with the plant-engineering elements and the organizational interface as regards the protection of completed roofing work on which systems are later installed.

For this purpose, and to initially identify and resolve all serious problems including interface ones which are identified on the roofing, the project roofing interfaces were analyzed. In particular, planning of the treatment of the technical and organizational interfaces was done after they had been identified by means of the calculation of suitable matrices of relation and treatment tables.

For example, the interface between the roofing and the electric plant conduction was analyzed both for the adoption of suitable systems by means of the detail drawing (atriums) and by co-ordinating the plant planning work so as to anticipate a flexible conduction scheme. In particular, what is required is the making of a series of decisions before the passing of the electric cables in the roofing.Specific measures of prevention were finalized to resolve particularly sensitive areas regarding the seriousness of the consequences and for the difficulties in checking and treating non-conformities. Special attention was paid to the designing of floor drilling and a specific procedure for variations in the layout of the holes owing to variations in the design of the systems. Work on parts of the finished roofing is one of the most important procedures to fulfil the criteria of waterproofing reliability.

Other points made with the object of specific prevention were, for example:

- execution of the footing;
- execution of the joints and sealing of the joints;
- execution of the practicable layer.

The checks were divided into critical points and shutdown points for which two distinct procedures were defined for the level of formalization and organizational work required. For both of these, both the type and frequency of control required, the person in charge of the control, and so on, were identified.

RESULTS

The definition of contractual laws which make the subcontractor collaborate in the definition of the quality plan is the decisive element in sustaining the development of experimentation regarding the grading of flat roofing in the project studied. The permanent state of emergence of the concurrent processes requires the active participation of the partners in the development of quality planning; the planning of design work compared to the milestones of construction. Technical risk analysis has proved to be an excellent instrument to manage planning development mainly according to the need for analysis completeness and efficient identification of risk factors and for the evaluation of relative importance.

Moreover, by means of risk analysis it was possibile to correctly classify partners' concurrent planning work which is very heavy in terms of men/hours dedicated to designing. The integration of the execution dossier with the quality plan has enabled the simultaneous comparison of the development roofing work details, in collaboration with the worker, and the planning of preventative measures and controls.

The development of the plan and the dossier required five meetings with the project partners to add up the preparation time and the individual work done by each of the partners. Considering the experimental nature of the work the result was satisfactory as regards the realization of the technical aspects while collaborative work management requires substantial improvement to be used quickly. For this reason both the greatest sensitivity and detail in contractual aspects are very important in making explicit the service sought-after by every contractor or sub-contractor. The extension of the experimentation to the construction planning in other planning areas requires the improvement and specification of concurrent planning procedures to considerably reduce the costs in men/hours and to make such procedures more efficient.

The application of FMEA to the construction management requires a substantial methodological innovation respect both quantitative and qualitative approaches.

The innovation introduced results from a qualitative approach that requires a careful specification of risk conditions and effects in construction process, and that requires a validation of the evaluation criterions.

The condition specification is obtained means the analysis of effective and particular factors which affect a project. The validation of the evaluation is achievable through objective and accurate criterions.

The pilot study carried out enables the evaluation of the general quality management implementation procedure, and its extension by using a PDCA (Plan Do Check Action) approach and the outlining of foreseeable results deriving from an extensive approach. The experimentation obtained information useful for increasing the understanding of tool usability by the personnel involved in the first project phases up to the on site management of technical criticality: further improvements are dealing to implement procedures for risk analysis in collaborative construction networks and to support the project audit.

CONCLUSIONS

The paper presents a critical re-examination of the state of the art of quality management in the building industry. To this end research was carried out on one of the largest Italian engineering companies which constructs business centres. The subject of the research project was the system of business quality management, the diagnosis of pathological processes and the experimentation of instruments to set up improvement processes. Results showed that the market where the company operates has permanent conditions of instability and uncertainty which make the normalization of contractual relationships between engineering, constructor and subcontractor difficult, through the certification of the quality system. The lowering of the requirements needed to obtain certification has introduced a decisive discrepancy between the formal state of certified quality and the real state of the company's qualification. Such a discrepancy risks leading to distrust between the partners of the project towards the efficiency of control techniques if not aimed towards effective results of total quality.

A FMEA technique for building construction could be the most important tool in managing quality plans to obtain a suitable and adequate and subsequently more efficient system to build in conformity with specifications. Given the nature of the construction process and specifically, the uncertainty and the environmental, technical and organisational complexity, a tool is needed that integrates the analysis and treatment of environmental, technical and organisational risk factors. The analysis of risk factors, the identification of criticality conditions and the evaluation of every critical point of the project together allow the linking up of data on failure modes, obtainable from technical literature, regulations, on-site findings, personnel expertise, to specific risk prediction for a precisely identified project. This allows the application of an FMEA-type tool to episodic production processes such as building sites and to make non-quantitative evaluations from which it is possible to identify judgement parameters. A common classification of risk factors can help technicians and managers in organisational and technical risk analysis. Technical risk assessment in building construction emphasises the role of project quality planning in client satisfaction and should be one of the main tools for evaluating the reliability of quality systems.

REFERENCES

[1] Mecca S., (1996). The role of Organisational Risk Analysis in improving Performances of a Building in relation to Probability of Conformity of Site Operations, Proceedings of 3rd International Symposium CIB - ASTM - ISO - RILEM "Application of the Performance Concept in Building, Tel-Aviv, Israel, December

[2] Mecca S., Masera M. (1998). A Technical Risk Analysis for the Quality Planning, Proceedings of 14th World Congress on Project Management 98 (IPMA), June, Lubljiana, Slovenia

[3] Mecca S., Masera M. (1998). Grading and management of nonquality risk in civil construction project management, Associazione Italiana di Ingegneria Economica, Giornata AICE 1998, November, Università Bocconi

[4] Mecca S., Masera M. (1998). Implementing Quality through Risk Analisys and Plans in Construction Management, Project Management Research Workshop: Vienna V, University of Economics and Business Administration, Vienna.

[5] Mecca S., Masera M. (1999), The technical risk analysis in construction through a FMEA methodology, ARCOM - Association of researcher of Construction Management, 15TH Annual Conference and Annual General Meeting, Liverpool September

[6] Stamatis D. H., (1995). Failure Mode and Effect Analysis, FMEA from Theory to Execution, ASQ Quality Press, Milwaukee, Wisconsin

TOTAL QUALITY MANAGEMENT (TQM) – THE IMPACT?

John Smallwood
Department of Construction Management, University of Port Elizabeth, South Africa.
coajjs@upe.ac.za

TQM, which encapsulates quality, is a strategy which links the processes of health and safety (H&S), productivity and quality, the objective being to continually improve business performance.

Traditionally, the motivation for H&S has been legislation, as opposed to enhanced business performance. Secondly, cost, quality and time have been the project parameters used to assess contractors' likely performance at bidding stage, and actual performance during, and after completion of construction. The aforementioned are possibly attributable to a lack of appreciation of the dynamics and synergy which exist between H&S and the other project parameters of, cost, environment, productivity, quality, time, and client and worker satisfaction.

Given the findings of literature and the limited amount of descriptive research conducted to date, a postal survey was conducted among a group of South African H&S 'best practice' (H&S) general contractors (GCs) to determine the impact various phenomena have on the traditional and non-traditional project parameters. The computation of an importance index (II) enabled the relationship between the phenomena and project parameters to be quantified. The phenomena are: inadequate H&S; accidents; poor productivity; rework, and poor project time performance. The project parameters are: cost; environment; H&S; productivity; project time; quality; client, and worker satisfaction. 91.7% of the relationships have II values greater than the midpoint value, which indicates that the phenomena have the equivalent of, or more than an impact on the various parameters.

Keywords: TQM, H&S, synergy, impact

LITERATURE

Introduction

The Associated General Contractors of America AGC (1992) defines TQM as: "A continuing process of improvement involving all aspects of the business." According to Levitt and Samelson (1993) TQM has as its main thrust continuous improvement in health and safety (H&S), productivity, quality, and employee and client satisfaction. The TQM mission in construction is to construct a quality product – an error-free one – for the customer by preventing errors in the construction process. TQM is the linkage of the processes, which deal with H&S, productivity, quality and satisfaction, with the real benefit being the synergy between them (Levitt and Samelson, 1993).

Myths and Reality

Levitt and Samelson (1993) maintain that myths such as "Accidents are inevitable in a dangerous industry like construction" and "Our first priority has to be getting the job done" can injure people, and cost a project and a contractor a great deal of money. H&S and productivity can be achieved simultaneously without any trade-offs - there are two reasons why H&S and productivity complement each other. The first is that certain management techniques, such as pre-planning make it easier to realise both goals e.g. planning enables organisation for both H&S and efficiency. The second is that emphasis on costs and schedules have been found to be counter productive, creating tension and pressure in workers with the resulting likelihood of accidents and mistakes.

According to Levitt and Samelson (1993) outstanding site managers were skillfully combining the basic ingredients of TQM – H&S, productivity and quality – on their sites before the term had begun to be seriously discussed; they had discovered the secret of supervisor site management: begin with excellent H&S and high productivity will follow. A job-site manager who successfully completed a 350 000 work-hour job with only US$8 000 in medical costs concurs: "You don't have to sacrifice productivity for safety. The safer the crew works, the quicker they work. The more safety you have, the more productivity you have."

Synergy

The AGC (1992) defines synergism as "The interaction of different entities so that their combined effect is greater than the sum of individual efforts." To facilitate TQM and to enable it to proliferate in the organisation, requires that quality efforts be linked to, among others, H&S and productivity.

Research conducted among project managers (PMs) in South Africa (Smallwood, 1996) determined, inter alia, that productivity (87.2%) and quality (80.8%) predominated in terms of aspects negatively affected by inadequate H&S (Table 1).

Table I. Aspects negatively affected by inadequate health and safety (Smallwood, 1996).

Aspect	Response (%)
Cost	72.3
Environment	66.0
Productivity	87.2
Quality	80.8
Schedule	57.4
Client perception	68.1

95.8% of PMs also stated that inadequate or the lack of H&S increases overall project risk. Risk increases as a result of increased variability of resources.

Relationships

H&S and Productivity

Productivity is simply a measure of the ratio between the output of a process and the input of resources needed for it (Humphrey and Halse, 1990). Consequently, any increase in the amount of inputs as a result of inadequate H&S and, or accidents, qualifies the relationship between H&S and productivity.

Given that overall productivity can be divided into three sub-measures, namely, availability, utilisation and efficiency (National Productivity Institute, 1994), substantial opportunity exists for inadequate H&S and, or accidents to impact thereon.

H&S and Quality

Manzella (1997) maintains excellence is only achieved when H&S and quality are integrated. Lo (1996) says H&S management reduces accident losses and contributes to the achievement of optimum cost, which is an essential element of quality management. According to Dias and Curado (1996), accident statistics are similar to defects. Lo (1996) also reasons that H&S is invariably a quality standard, as it is included as a requirement in various contracts.

In practical terms, H&S in the form of, inter alia, optimum working platforms which facilitates access, and optimum lighting, which facilitates visibility, engenders the achievement of quality (Smallwood, 2001).

Productivity and Quality

Research conducted among PMs working on high-rise projects in Indonesia determined rework to be the most severe cause of low productivity (Kaming et al., 1996). The aforementioned is cited in the context of the direct impact rework has on labour productivity as a result of the increase in the cost of inputs. However, rework negatively affects labour productivity indirectly due to its demotivating effect. Based upon a cross-analysis of demotivators during research conducted in Thailand, rework was ranked fourth and fifth by supervisors and workers respectively (Ogunlana and Chang, 1998).

H&S and Schedule

Research conducted in the USA determined H&S and schedule to be mutually reinforcing (Hinze, 1994). Other research conducted in the USA determined that projects that were behind schedule and overrunning budget to have higher recordable accident rates than projects that were meeting schedule and budget (Rodriguez et al., 1996). According to Hinze (1997) supervisors who meet schedule also realise the best H&S performance. In fact H&S and success in scheduling are dependent. Falling behind schedule results in an increase in production effort which increases the chance of accidents.

Productivity and Schedule

According to Chan and Kumaraswamy (1995) labour productivity is a significant intrinsic factor affecting the overall project schedule. However, Marchman (1990) maintains schedule changes have a dramatic impact on labour productivity. When work is planned it is organised according to an orderly flow of resources based on a logical sequence of activities. Consequently labour productivity is severely affected when the orderly plan is impacted by a schedule change as a result of: out of sequence work and upset rhythm; reassignment of workers and consequent non-optimum team sizes; increased density of workers; conflicts

RESEARCH

Sample Frame

The sample frame consisted of 26 GCs which had achieved placings in the BIFSA National H&S Competition and, or BIFSA 4 or 5-Star H&S gradings on one or more of their projects. 11 GCs responded, which represents a response rate of 42.3%.

Analysis of Data

Given that respondents were required to respond in terms of impact on a scale of 1 (major) to 5 (no) and the extent to which they agree, it was necessary to compute an importance index (II) with a minimum value of 0, and a maximum value of 4, to enable a comparison of, and to rank various phenomena, parameters and interventions. The II is calculated using the formula:

$$\frac{4n_1 + 3n_2 + 2n_3 + 1n_4 + 0n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)}$$

where	n_1	=	Major impact (1) / Strongly agree
	n_2	=	Substantial impact (2) / Agree
	n_3	=	Impact (3) / Neutral
	n_4	=	Minor impact (4) / Disagree
	n_5	=	No impact (5) / Strongly disagree and Unsure

Findings

Table 1 indicates the extent to which various phenomena impact on various project parameters in terms of impact on a scale of 1 (major) to 5 (no). The relationships have been ranked within the phenomena and overall.

It is significant that the II values of 33 of the 36 relationships are greater than the midpoint value of 2.0, which indicates that most of the phenomena have the equivalent of, or more than an impact on the various parameters. It is also significant that 16 of the 36 relationships have II values greater than 3.0, which indicates that the respective phenomena have a 'major' / 'substantial' impact on the respective parameters.

The top five II values recorded are: 'poor productivity' relative to 'project time' (3.90); 'poor project time performance' relative to 'cost' (3.82); 'poor productivity' relative to 'cost' (3.81); 'rework' relative to 'productivity' (3.73) 'poor project time performance' relative to 'client satisfaction' (3.73). These were followed by: 'rework' relative to 'cost' (3.63); 'accidents' relative to 'cost' (3.55); 'accidents' relative to 'worker satisfaction' (3.46); 'rework' relative to 'project time' (3.46); 'accidents' relative to 'productivity' (3.36), and 'poor project time performance' relative to 'productivity' (3.36) ie. three of the top eleven II values are related to accidents.

Table II: Impact of various phenomena on various project parameters.

Relationship		Impact (%)					II	Rank (with in)	Rank (over all)
		Major …………………… No							
Phenomenon	Parameter	1	2	3	4	5			
Inadequate health and safety (H&S)	Productivity	27.3	54.5	18.2	0.0	0.0	3.09	1=	14=
	Worker satisfaction	45.4	18.2	36.4	0.0	0.0	3.09	1=	14=
	Quality	18.2	45.4	36.4	0.0	0.0	2.82	3	21=
	Client satisfaction	27.3	27.3	18.2	27.3	0.0	2.73	4	23=
	Cost	36.4	45.4	9.1	9.1	0.0	2.64	5	25=
	Environment	27.3	9.1	54.5	9.1	0.0	2.55	6=	28=
	Project time	18.2	45.4	9.1	27.3	0.0	2.55	6=	28=
Accidents	Cost	72.7	9.1	18.2	0.0	0.0	3.55	1	7
	Worker satisfaction	63.6	27.3	0.0	9.1	0.0	3.46	2	8=
	Productivity	45.4	45.4	9.2	0.0	0.0	3.36	3	10=
	Project time	27.3	45.4	27.3	0.0	0.0	3.00	4	17=
	Quality	9.1	45.4	27.3	18.2	0.0	2.46	5=	31=
	Client satisfaction	36.3	27.3	9.1	27.3	0.0	2.46	5=	31=
	Environment	9.1	18.2	45.4	27.3	0.0	2.09	7	33
Poor productivity	Project time	90.0	10.0	0.0	0.0	0.0	3.90	1	1
	Cost	90.9	0.0	9.1	0.0	0.0	3.81	2	3
	Client satisfaction	36.4	45.4	9.1	9.1	0.0	3.09	3	14=
	Quality	27.2	36.4	36.4	0.0	0.0	2.91	4	20
	Worker satisfaction	45.4	9.1	18.2	27.3	0.0	2.73	5	23=
	H&S	27.3	27.3	18.1	27.3	0.0	2.55	6	28=
	Environment	9.1	18.2	36.4	9.1	27.3	1.55	7	36
Rework	Productivity	72.7	27.3	0.0	0.0	0.0	3.73	1	4=
	Cost	63.6	36.3	0.0	0.0	0.0	3.63	2	6
	Project time	54.5	36.4	9.1	0.0	0.0	3.46	3	8=
	Worker satisfaction	45.4	36.4	18.2	0.0	0.0	3.27	4	12
	Client satisfaction	54.5	18.2	18.2	9.1	0.0	3.18	5	13
	Qualtiy	27.3	45.4	27.3	0.0	0.0	3.00	6	17=
	H&S	36.4	27.2	9.1	18.2	9.1	2.64	7	25=
	Environment	9.1	9.1	54.5	18.2	9.1	1.91	8	34=
Poor project time performance	Cost	81.8	18.2	0.0	0.0	0.0	3.82	1	2
	Client satisfaction	90.9	0.0	0.0	9.1	0.0	3.73	2	4=
	Productivity	45.4	45.4	9.2	0.0	0.0	3.36	3	10=
	Quality	27.3	54.5	9.1	9.1	0.0	3.00	4	17=
	Worker satisfaction	36.3	27.3	18.2	18.2	0.0	2.82	5	21=
	H&S	27.3	27.3	27.3	18.1	0.0	2.63	6	27
	Environment	9.1	18.2	45.4	9.1	18.2	1.91	7	34=

Given that the mean values of the IIs are above the midpoint value of 2.0, the contractors can be deemed to be in agreement with the use of the parameters to prequalify and assess contractors in terms of potential and actual performance (Table III).

Table III. Extent of agreement / disagreement relative to the use of various parameters for the prequalification and assessment of contractors.

Parameter	Prequalification		Assessment		Mean	
	II	Rank	II	Rank	II	Rank
Quality	3.50	1=	3.78	1	3.64	1
H&S	3.40	3	3.56	2	3.48	2
Time	3.50	1=	3.44	3=	3.47	3
Environment	3.20	4	3.44	3=	3.32	4
Cost (bid price)	3.10	5	3.11	5	3.11	5

CONCLUSIONS

International literature indicates that both the traditional and non-traditional project parameters complement each other as a result of synergy. Conversely, various 'negative' phenomena have a substantial impact on the traditional and non-traditional project parameters.

The descriptive survey findings reinforce the findings of literature. Accidents, poor productivity, rework and poor project performance predominate among the phenomena in terms of impact on the project parameters.

REFERENCES

[1] Anderson J. 1997. The problems with construction. The Safety and Health Practitioner, May, 29-30.

[2] Bossink B.A.G., Brouwers H.J.H. and Kessel R.A. 1996. Financial consequences of construction waste. In Proceedings of the 1996 CIB W89 Beijing International Conference – Construction Modernization and Education, Beijing, China, CD-file://D1/papers/120-129/122/p.122.htm.

[3] Chan D.W.M. and Kumaraswamy M.M. 1995. A study of the factors affecting construction durations in Hong Kong. Construction Management and Economics, 13 (4), 319-333.

[4] Coble R.J. and Kibert C.J. 1994. The Environment as a Construction Safety Concern. In Proceedings of the Fifth Annual Rinker International Conference Focusing on Construction Safety and Loss Control, Gainesville, Florida, 535-542.

[5] Dias L.M.A. and Curado M.T. 1996. Integration of quality and safety in construction companies. In Proceedings of the First International Conference of CIB Working Commission W99 Implementation of Safety and Health on Construction Sites, Lisbon, Portugal, 21-28.

[6] Hinze J.W. 1994. The Role of Project Coordination in Construction Safety. In Proceedings of the 5th Annual Rinker International Conference focusing on Construction Safety and Loss Control, Gainesville, Florida, 521-534.

[7] Hinze J.W. 1997. Construction Safety. Prentice Hall, Inc., New Jersey.

[8] Humphrey J. and Halse F. 1990. Profit from Productivity. Juta & Co. Ltd., Cape Town.

[9] Kaming P.F., Olomolaiye P.O., Holt G.D., Kometa S.T. and Harris F.C. 1996. Project managers perception of production problems – an Indonesian case study. Building Research and Information, 24 (5), 302-309.

[10] Levitt R.E. and Samelson N.M. 1993. Construction Safety Management. 2nd Edition. John Wiley and Sons, Inc., New York.

[11] Lo T.Y. 1996. Safety: An element of quality management. In Proceedings of the First International Conference of CIB Working Commission W99 Implementation of Safety and Health on Construction Sites, Lisbon, Portugal, 195-201.

[12] Manzella J.C. 1997. Achieving safety Performance Excellence Through Total Quality Management. Professional Safety, May, 26-28.

[13] Marchman D. 1990. Schedule Influence on Productivity. The American Professional Constructor, February, 4-6.

[14] National Productivity Institute (NPI). 1994. Productivity and Productivity Improvement Symposium, University of Port Elizabeth, Port Elizabeth.

[15] Olomolaiye P.O. and Price A.D.F. 1989. Construction operatives – motivation and productivity. An evaluation of motivation variable in construction operatives in the UK. Building Research and Practice, 17 (2), 114-120.

[16] Price A.D.F. 1992. Construction operative motivation and productivity. Building Research and Information, 20 (3), 185-189.

[17] Productivity SA. 1995. Neil Muller Communication the key. Productivity SA, September/October, 28.

[18] Rodriguez Y.A., Jaselskis E.J. and Russel J.S. 1996. Relationship between project performance and accidents. In Proceedings of the First International Conference of CIB Working Commission W99 Implementation of Safety and Health on Construction Sites, Lisbon, Portugal, 251-257.

[19] Smallwood J.J. 1995. The Influence of management on the occurrence of loss causative incidents in the South African Construction Industry. Unpublished MSc (Construction Management) Dissertation, University of Port Elizabeth, Port Elizabeth.

[20] Smallwood J.J. 1996. The role of project managers in occupational health and safety. In Proceedings of the First International Conference of CIB Working Commission W99 Implementation of Safety and Health on Construction Sites, Lisbon, Portugal, 227-236.

[21] Smallwood J.J. 2001. The influence of ergonomics on project performance. In Proceedings of the CIB World Building Congress, Wellington, New Zealand, HPT 11.

[22] Smallwood J.J. and Rwelamila P.D. 1996. Department of Public Works Enabling Environment Initiative Final Report on Initiatives to Promote Health and Safety, Productivity and Quality in South African Construction. Unpublished report.

[23] Smallwood J.J. and Rwelamila P.D. 1998. The need for the implementation of Quality Management Systems in South African construction. In Proceedings of the CIB World Building Congress, Symposium D: Managing for Sustainability – Endurance Through Change, Gavle, Sweden, 2225-2234.

[24] The Associated General Contractors of America (AGC). 1992. An Introduction to Total Quality Management. AGC, Washington, D.C.

[25] The Business Roundtable. 1991. Improving construction safety performance. Report A-3. The Business Roundtable, New York.

[26] The Business Roundtable. 1993a. Absenteeism and Turnover. Report C-6. The Business Roundtable, New York.

[27] The Business Roundtable. 1993b. Scheduled Overtime Effect on Construction Projects. Report C-2. The Business Roundtable, New York.

IMPROVING ECONOMICAL EFFICIENCY FOR A QUALITY MANAGEMENT SYSTEM OPERATED AT A JAPANESE CONSTRUCTION COMPANY

Masaei Suzuki
Quality & Environment Management Department, Kumagai Gumi Co., Ltd, Japan
msuzuki@ku.kumagaigumi.co.jp

Effective implementing of quality management systems is now a serious issue for company management. In the Japanese construction industry, companies began to get ISO9000 certification around 1996 with the intent to differentiate themselves from other companies that do not have ISO9000 certification. At that time, the aim of building quality management systems was not to construct the buildings effectively but to pass the certification audit. In other words, the action of establishing the quality management system focused mainly on building the document control system to pass the audit.

As a result, building defects discovered after hand-over to the customers did not decrease even after two to three years of getting the certification, while some types of defects even increased. The management of our company directed us to improve the quality management system in order to get economical effectiveness. After having practiced various measures, we got the performance of improvement. This paper introduces our approach to improvement; in addition, I will discuss how we can deal with the 2000 revision of ISO9000 for the effective and efficient quality management system.

INTRODUCTION

During the serious recession of Japanese economy, the circumstances of the construction industry market have demanded severe competition due to reduction of the investment in facilities from other industries.

Severe circumstances of competition had forced construction companies to accept low price orders. They therefore had to reduce construction costs, such as material, labor and management costs. However, if the company cut the cost without assurance for quality, they would lose credibility. The compensating cost would then become more than the cut cost. As a result, the company would lose competitive power. What's more, the price war would lead to intensifying consciousness of consumers' rights, which in some cases would increase construction costs if the consumer's request is unreasonable.

For instance, no matter how high the noise from the neighborhood of a condominium is, it varies in accordance with the feeling of individuals. Companies don't want disputes with consumers in Japan, because they arc afraid of losing their reputation. Furthermore the newspapers and other media often attack construction companies in support of the consumers. Therefore the compensating cost has been increasing day by day. These affairs have worsened the business situation.

The Japanese construction industry introduced quality management on the order of TQC, quality assurance structure and ISO9000 as I mentioned in my paper "Implementation of Project Management based on Q E S and those Issues in Japanese Construction Industry and in Kumagai Gumi" (Suzuki, CIB International Conference at Lisbon, 2000). However, Japanese general contractors don't have any skilled laborers in their organization, so most of qualities of individual works are dependent on the ability of the outsource laborers. Under these constraints, this paper discusses how we made high quality buildings in order to maintain our competitive competence.

This paper consists of three sections. In the first section, it discusses what is occurring in the Japanese construction industry.

Then, in section two, some methods for effectively improving quality performance that have been practiced at construction sites are presented.

In the section three, some problems experienced in the construction department of a company are mentioned and the solutions for those problems at Kumagai Gumi are proposed.

Finally, some conclusions and recommendations about enhancing QMS are proposed.

REDUCING COST AT CONSTRUCTION SITES BY IMPROVING QMS

As means for reducing cost at construction sites, there are the following three kinds of methods:

- Reduction of rework (cut the hidden losses and the hidden costs)
- Optimizing documentation by focusing objectives (consideration for the effect gotten by documentation)
- Sharing information fed back from company's wide executions of works (sharing examples of success and failure)

Those presently being practiced by Kumagai Gumi are mentioned in the following subsections.

Reduction of Rework at Construction Work

Construction work is unique, which means the work varies in accordance with customers, constraints, assumptions, and the skill of labor. Therefore there are no sites that exist without reworking defects, even if they plan in any strict way in advance. As a result, the subcontractors always include repair or rework costs in their estimates. If the rework cost were nearly zero, they could offer a more reasonable price of work.

There are two considerable ways to reduce the rework cost.

- To take measures to prevent defects or nonconformance predicted before execution, so called "preventive action"

- To take action immediately after the incidents occur

In the first case, for example, if there is a cause of defect in the design documents, we should change the specification such as the material or procedure of the design before execution because we could save rework costs, in many circumstances. The important idea here is that some defects must appear as a matter of probability if humans do something. Therefore the most important thing is that the balance between the preventive cost for defect or nonconformance and the counteraction cost resulting from repair of the defect should be considered. Action that should be done for it is that the construction company should thoroughly review design documents after the contract is awarded and before execution of the work. Of course, the responsibility for design documents must be with the designer but in Japan, the General Contractor has to pay for most of the defects caused by design documents, as I mentioned in another report at Lisbon last year.

For this review, Kumagai Gumi uses a checklist based on lessons learnt in the past. The items of the list are classified into 15 categories. (Table I) The article contains criteria and refers to a manual; the Prevention manual for defects-claim at building construction work (BCS, Japan). (Table II) The articles are reviewed every year based on the defects and claims of the previous year.

Construction projects are enormous assembly works that process and assemble large number of various parts. It is therefore very useful for forecasting what may occur in the process that requires the exercise of intuition owned by a skillful expert. Intuitive judgement by the expert is a special information processing ability with which God blesses humans, namely, humans can retrieve the appropriate judgement from the amount of information based on experience instantaneously, and such ability exceeds that of enormous super computer systems. Most construction work depended on intuitive judgement ability in the past. However, after the introduction of TQC, the data based on fact is now more important than intuition. For that reason, intuition has been slighted for a long time. As the result, defects and nonconformance caused by less experienced site people has been increasing. To effectively utilize the intuition of experienced people, Kumagai Gumi is implementing review of design documents by them before construction. Namely, in case a building is constructed according to the design documents before execution of the works, they simulate to determine whether any significant quality affects exist or not, using their experience and intuition. If they forecast some defects, we can take measures for it such as changing the design, and review the manner of construction as a preventive action.

Table I. Categories of check sheet for prevention of defects and claims

Categories	Design	construction planning	construction
Cracks	14	19	15
Leak from window, door and seal	4	8	3
Cracks and leak from balcony	14	13	11
Leak from asphalt waterproofing roof	1	14	7
Leak from single ply roof	0	2	5
Leak from waterproofing film	1	1	6
Leak from FRP water proofing	1	3	7
Tile come-off the external wall concrete	8	8	4
Paint come-off the external wall concrete	2	0	6
Mortar come-off the external wall concrete	1	5	8
Floor slab sag or sinking	10	12	13
Condensation	14	0	0
Noise from next room	5	0	1
Test for leak	0	1	2
Fire wall	0	0	3
total	75	86	91

Table II. Example of check sheet for prevention of defects and claims

Stage	Refer to manual	Check Item Criteria for check	Check point
Planning Control	**Page 42.6**	**Delivery time for ready mixed concrete** Criteria Time **Temperature T>=25 within 90min.** **T< 25 within 120min** **(use admixture) depend on approving**	**1. plant name:** **2. cast time at construction joint:**
Planning Control	**Page 42.19**	**Contents of concrete aggregate** **Chloride: less than 0.04%** **(0.02%: long term use)**	**1. don't forget measure of chloride** **2. in case of concrete: chlorine ion: less than 0.3kg/cubic meter**
Planning Control	**Page 43.20**	**Water ratio : less than 185kg/ cubic meter**	**1. check mix design report** **2. see technical sheet C-018 "Check point for mix design"**

In the second case, even if we may predict occurrence of defects or nonconformance, but the result of the affairs is not so significant as to require the taking of preventive action, and the cost of preventive action is too high as compared to the benefit of prevention. Anyway, Kumagai Gumi must take adequate treatment measures for the defects of nonconformance. It's important to monitor appropriate parameters that can detect matters for treatment as early as possible, and to plan treatment for it before execution.

As a monitoring measure, Kumagai Gumi implements quality patrols on site. The site manager implements monitoring according to parameters planned previously. At that time, they use not only the planned checklist but also their experience and intuition. This is because, at construction sites, many unforeseen incidentes may occur. At Kumagai Gumi, there is a serious problem on that point, namely, the resignation of experts due to organizational restructuring has resulted in an increase in the number of less experienced site managers. In order to support the managers, the company implements periodical patrols by experts in charge of quality management.

Optimizing Documentation by Focusing Objectives

ISO9000 requires much documentation at construction sites. Therefore Kumagai Gumi had a format to prepare documents to be used for such planning and reports for saving time. The document can be completed by only inputting some particular conditions at the site in the format. It becomes very useful in case of an audit by a third party, because we can use the format to prepare documents at any sites in Kumagai Gumi. However, there were many problems such the documentation way. Site managers had not been adequately conscious of the real purpose of the documents, that in fact the purpose of the documentation was to receive audit by third party auditors. The format for documentation had been increasing day by day to suit various sites ranging from small to big, from residences to hotels. As a result, at a small site in Kumagai Gumi, the construction plan documented for a big site according to the company's format could not be executed too much for such a small site. Although one purpose of documentation is to demonstrate evidence, it is not for management. The essential purpose of documentation should be to serve as a planning and communication tool for implementing management systems. Originally, the purpose of implementing quality management systems was realization of customer requirements, but after introducing ISO9000, they had been misunderstanding that the purpose of ISO9000 was documentation. One of reasons for such a misunderstanding is that they think that "introduction of ISO9000 is ordered by the company and it's not for changing their original work".

Kumagai Gumi took corrective action in regard to the misunderstanding of documentation. Namely, the company made changes to simplify the formats, and most of the documents were scripted by matching their condition such as scale and use, not only input for automatic documentation. There was another advantage of the measure, namely that the site manager had to consider the purpose of the document when they produced the document. It made the site manager consider the objectives of the work and project. The important thing is that they came to have the consciousness that: "we had executed good work for quality since before, ISO9000 only requested us to make minimum documents for demonstration, and that such documents are not for audit but for quality management based on quality objectives."

As a result, Kumagai Gumi achieved reduction of documents at the site. It makes the site manager more conscious about implementing optimum management based on the objectives. When they make the document, they simulated the execution and know what would occur at that site as information for preventive action.

Sharing Information

Information about successes or failures of the project was being shared before the introduction of ISO9000 in Kumagai Gumi as one of measures of "Kaizen". After ISO9000 required corrective action and preventive action, the company arranged the manner of sharing system as the procedure for implementing those requirements. Originally, construction sites had been operated with the knowledge and experiences of project managers. They therefore had no habit of learning the knowledge of other managers. However, there are over one thousand sites in one company that are called "General Contractor", and the sharing of this information is a very effective manner of reducing the repair cost of defects.

In Kumagai Gumi, when some serious defects occur, the site manager prepares a "feedback sheet", and distributes it to all of their sites. The feedback sheet contains information such as the fact and circumstances of the defect, cause, measures for eliminating the cause, and effectiveness of the measures.

ISSUES EXPECTED TO BE SOLVED IN THE COMING FEW YEARS

In Japan, it is not only the site manager that assumes responsibility for the project but also the general manager of the construction department of the company works together with him. If it's necessary, the general manager even assumes responsibility instead of the site manager for their customers. The general manager plays an important role on the project as to quality in Japan. Kumagai Gumi improved performance to a certain extent by improving its management system. As a result of those measures taken at construction sites, compensating costs saved amounted to one million dollars last year in civil construction work. However, the costs increased in building construction work. There are other causes of defects at building construction sites. We researched the cause of defects. As a result, there are causes not only at construction sites but also at the construction department in charge of controlling construction sites. From now on, we should improve the management system focusing on the construction control department.

The issues at the construction department level are mentioned as follows.

Issues on Standardization

As one of tool for TQC, standardization made a great success in the product industry which produced in large scale. The construction industry introduced standardization for high quality and high effectiveness. Namely, "Kaizen" and standardization are introduced through the leadership of construction departments.

As a result, they succeeded in terms of producing the same quality product, but they made too many company regulations aimed at controlling all construction sites in the same way. Those regulations were made based on past practices at big sites, so the procedure and format could not be simply adopted because each site had various conditions.

There are problems with the following points in the construction department:

- There are too many methods for construction as standard rules, so the site manager doesn't consider the construction plan, and doesn't improve their own technical skills.
- The site managers don't assume their responsibility because most of the manner of construction is given by the company.
- The site manager doesn't make efforts to create new methods for construction because company gives construction methodology in detail.

The General manager makes the site manager submit too much information as reports to top management, so the site manager wastes too much time for it.

Measures to Solve the Issues

Now, we understand that there are many problems in the construction department, so we will implement some measures for improving our quality management. Furthermore we have to change the quality management system for revising ISO9001:2000. ISO9001:2000 emphasizes management responsibility and the process approach as being conscious of the management system. We will reconstruct the ISO9000 management system, using the process approach based on lessons learnt from various issues I mentioned earlier.

At first, we will review our workflow by the analysis method of input-output as defined in ISO9000:2000. Then we can get at what is the most important process in our work. When we analyze the workflow, we can use the work breakdown structure (WBS) defined by A Guide to the Project Management Body of Knowledge (Project Management Institute, 1996), and breakdown from top policy and objectives. Then, we can get the optimum process workflow, and top management can view the system from a bird's eye point.

Kumagai Gumi has a big quality assurance process chart, so long as to be over 3-meters. At first, the chart was not so long. It gradually started containing many kinds of factors like cost, delivery, safety, and environment. Furthermore, many actions caused by some affairs, defects, incidents and so on were added. As a result it become such a huge chart. Originally, all site managers and function managers had to have an accurate grasp of the chart, but it had become too big to understand, so the chart has been becoming a dead letter.

After making the process workflow, we will replace the quality assurance process chart with process workflow. Then we can get an effective quality management system, and aim for maximum profit by using minimum resources.

CONCLUSIONS

Construction work is assembly work structured by tens of thousands of parts, like the Jumbo Jet, so it's impossible to make all procedures for each works. If you script the procedures like that, there may be a few tons of manuals as required in Jumbo Jet assembling. We make procedures for important works to be affected by the quality of the products. The most important thing is that each person working at the site is aware of the objectives of that work. Then they can become conscious of what the most important thing is that they have to do for quality. They can become conscious of what is a bad thing to make defects. Then they can be motivated to make good products. Good products produced by a good system and good consciousness for quality by people.

REFERENCES

[1] Building construction division, Check Sheet for Prevention for Defects and Claims, Kumagai Gumi Co., Ltd., Japan

[2] Yamaguchi Y, Prevention of defects sub-committee, Prevention Manual for Defects-Claim at Building Construction Work, BCS, Japan

[3] Duncan W, PMI Standards Committee, A Guide to the Project Management Body of Knowledge, Project Management Institute, USA

[4] Suzuki M, Implementation of Project Management based on Q E S and those Issues in Japanese Construction Industry and in Kumagai Gumi, in "Implementation of Construction Quality and Related Systems: A Global Update" proceeding of the International Conference in Lisbon, 2000, CIB Task Group TG36

[5] Suzuki M, Quality System sub-committee, Points of Measures for ISO9001:2000 Revision in Construction Industry, BCS, Japan

Enginyers Industrials de Catalunya
Associació/Col·legi

Les institucions dels **Enginyers Industrials de Catalunya** representen un col·lectiu de professionals compromesos amb la **seguretat**, la **prevenció** i el desenvolupament i la millora de la **qualitat de vida.**

L'ENGINYER INDUSTRIAL garantia de seguretat

Preufet Empresa Constructora

Sociedad Anónima

EDIFICIOS INDUSTRIALES
MANTENIMIENTO DE INDUSTRIAS
REHABILITACIÓN DE EDIFICIOS
CENTROS ASISTENCIALES
PROMOCIÓN Y GESTIÓN INMOBILIARIA

Tallers, 77 - 08001 Barcelona
Teléfonos: 93-301 73 31 - 93-301 74 25
Fax: 93-412 21 45

e-mail: preufet@retemail.es

Almacén: Cartagena, 160
08013 Barcelona
Teléfono: 93-265 42 92

AUTHOR'S INDEX