Designing for Safety and Health Conference Proceedings

26th and 27th June 2000

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Safety and Health
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working well together

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Working Well Together campaign which is led by the Health and Safety Commission's Construction Industry Advisory Committee (CONIAC), and is supported by the Health and Safety Commission and the Health and Safety Executive.

Designing for Safety and Health Conference Proceedings

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THE IMPORTANCE OF DESIGN IN ACHIEVING IMPROVED HEALTH & SAFETY: LESSONS FROM THE OFFSHORE INDUSTRY

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ABSTRACT

Since Piper Alpha, the offshore industry has undergone dramatic change in its approach to health and safety. In the 12 years since the disaster, pioneering ideas have made their way onshore often buttressed by the UK's interpretation of European Directives.

The Health & Safety Executive has followed the recommendations of Lord Cullen and has embraced a goal setting culture when drafting regulations with substantial contributions from industry. A new approach has been developed to meet goal setting and Risk Based design, but some perceive the approach to be expensive to implement.

The industry now routinely tries to look at the importance of safety in design but the iterations required do not always sit well with "fast track" projects.

Many ideas applied offshore were well established but needed a period of maturation to become more effective and some were indeed novel. As the country prepares for Lord Cullen's enquiry into another disaster, this paper looks at some developments in the management of health and safety offshore from the last enquiry. It reviews the successes, failures and whether some of the ideas could apply to other industry sectors.

Keywords: risk, performance standards, safety critical, life cycle, safety case

HISTORY

The world of offshore safety was thrown into shock on the 6th July 1988, when the North Sea oil platform Piper Alpha suffered an explosion and subsequently caught fire. The resultant enquiry chaired by Lord Cullen (Cullen, 1990) raised some 106 recommendations. The change of approach of regulation was profound, from prescription to goal setting and has needed further constructive collaboration to make it all happen. This paper describes some of the initiatives that have been developed and will venture an opinion on how successful they have been. We will recommend the application of some of those ideas to other sectors and identify the lessons learned from them.

STARTING AT THE BEGINNING

The overriding change in the legislation applicable to the offshore sector was the wholesale change from prescription to goal setting. This approach had been captured in the Health & Safety at Work etc. Act, (HMSO 1974) but following the recommendations from Lord Cullen it was applied wholeheartedly and specifically to one industry sector. However, even before the first legislation was drafted there were four activities recommended by Lord Cullen that were referred to as the "forthwith" studies based on the recommendation that they be carried out forthwith, before legislation was in place. This posed our first dilemma and gave us our first lessons.

THE FIRST HURDLES

A key "forthwith" study required consideration of an underwater barrier valve on pipelines connected to the platforms. These valves needed considerable effort to install and regular maintenance work by divers to maintain them in a suitable condition. Hitherto, many of these installations had no barrier valve at all, this activity introduced a considerable increase in diver activity, the most hazardous activity in the North Sea. Although an obvious and well-known concept, we were introducing risk transfer from one employee population to another, this issue was to arise on other occasions. As part of "offshore's" first brush with risk perception and risk aversion, the public with tacit support from the regulator did not want to see another major conflagration but unfortunately seemed ready to accept an increase in occupational hazards.

The principle of gross disproportion assists the judgement of balancing risks to disparate numbers of people, but it does not always give a clear answer. Societal concerns have always been a bedfellow of the safety profession and rightly so, but it is not always easy to determine a clear route to incorporate them into analyses in an appropriate fashion. The Risk Based Decision Framework published by UKOOA (UKOOA, 1999) is a useful tool to assist these decisions. The lesson for other sectors is that although risk transfer to the public at large may be unacceptable, risk transfer between different employed groups is not always easy to resolve.

A further "forthwith" study, related to the protection against explosions. The industry started to carry out tests on modelling explosions. Much research into explosions had until that time focussed on unconfined explosions, for example as might be experienced at oil refineries or gas transmission plants, primarily onshore applications. The industry adopted this research topic with considerable enthusiasm and tremendous strides were made into understanding the physics and dynamics of hydrocarbon explosions. However, there is now a serious questioning of what the industry has done; not because it is wrong but because the research effort may have been misplaced. For example, the risk of explosions in modules that are completely filled with an optimum (stoicheiometric) mix of hydrocarbon and air is undoubtedly remote, only in the current wave of research projects is the effect of off-stoicheiometric mix being investigated fully. These are not criticisms, the earlier work has enhanced our knowledge of modelling to the extent that these investigations can now be undertaken. However, in terms of the probability of large-scale explosions taking place, these rank well down the list of incidents causing fatalities offshore.

A typical pie chart of the spread of the forecast major accidents based on data collected to date and available in the public domain is shown below. Our lesson is to ensure that investigations and research are placed into context and to consider all phases of the project. Designing against a major hazard may exacerbate another one, and may increase construction effort and risk.

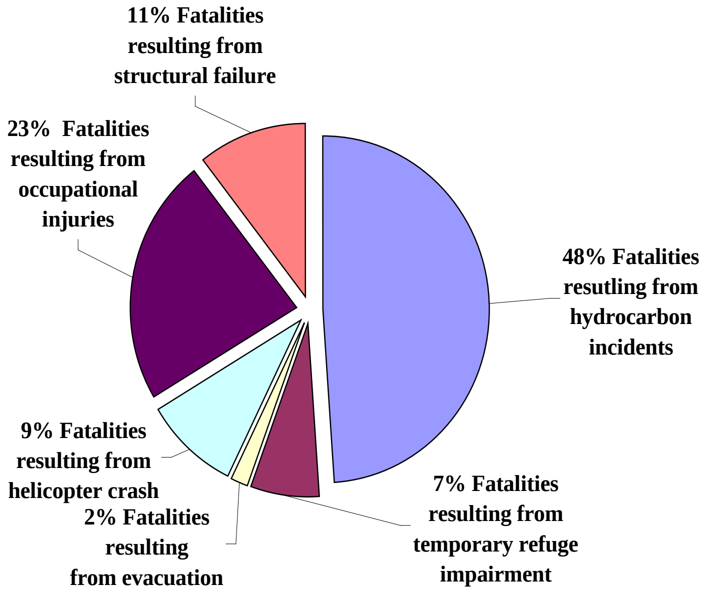

Figure 1 Percentage fatalities by incident type

It should be noted that the sector showing fatalities related to hydrocarbon releases will include a range of incidents, asphyxiation, fires as well as explosions, not to mention incidents related to the diesel and methanol stored on board. The trend for forecasting hydrocarbon events has been to consolidate them in this way as the events are mixed and fatalities and injuries cannot always be attributed to one stage of the escalation.

LESSONS FROM THE LAW

The Safety Case

The lynchpin of the new regulations was the Safety Case, (HMSO, 1992). This provided us with our first lessons in responding to the newly enacted laws. The offshore industry learned a great deal from the nuclear industry over the issue of safety cases but ultimately went their own way for some very good reasons. The nuclear safety case structure was a licensing system, the safety case was presented in parts and had to be accepted prior to the next stage being commenced. This was never the intention offshore. At the outset, the newly appointed Director of the Offshore Safety Division indicated that there was not to be a licensing regime for the offshore sector, and we feel that very few people would disagree with that stand, especially in light of current industry practice.

When the safety case regime was first initiated, many in the industry felt that the design phase of projects would lengthen in order to accommodate the additional work required, at the very least the extra time would allow more thinking and engineering.

However, the opposite has happened, the numbers of fast-track projects has increased and many have recently been let on almost ludicrously accelerated schedules.

Nonetheless, learning lessons from other sectors has been useful, the nuclear safety cases were submitted prior to particular activities being undertaken and were very substantial documents. The offshore documents are very much smaller and the successful ones have tended to reflect a dialogue that is going on anyway.

The lesson learned is that the dialogue can never take place early enough, the recent review of the Offshore Legislative Regime undertaken by Aberdeen University (AUPEC, 1999) highlighted a special concern over the early dialogue on Design Safety Cases.

A further “lesson learned” related to the apparently simple concept of what is goal setting? A goal based safety regime is all very well, but some definition of what the goals should be or encompass seemed very necessary.

The design contractors developed through their trade organisation (The British Chemical Engineering Contractors Association, BCECA) a three-tier structure for the definition of goals. This was developed from the design houses experience and missed a wider view, but it laid the basis of a next step for a thorough 3-tier definition. The structure that many of us finally used after further discussion was to split technical goals from management goals, the technical goals were able to be more clearly defined and used as the chosen nomenclature, a term recommended by the Health & Safety Executive (HMSO, 1997), namely the Performance Standard.

This structure was developed in more detail as the industry prepared guidance (UKOOA, 1995) for the next stage of regulation, Fire, Explosion and Emergency Response. (HMSO, 1995).

Fire, Explosions and Emergency Response

This next step in the definition of the goal setting regulations required a legal duty to manage the hazards arising from fire and explosion and to have in place a system for managing emergency response. This was the Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995, otherwise known as PFEER. The three-tier performance standard structure was modified to be more generally applicable, and incorporated the needs of the operators. The final guidance document did not include the full definitions but the outcome during discussions of the work group identified the structure described in figure 2.

- Top tier goal – The Risk Based Performance Standard; a statement of risk targets or limits that the plant or installation intends to achieve. A numerical measure.

- Middle tier goal – The Scenario Based Performance Standard, a description of the hazardous scenario that is introducing the risk. This can be a semantic description of the hazard, but is bespoke to the installation under review.

- Bottom tier goal – The System Based Performance Standard, a statement of the numerical targets that systems/equipment have to achieve to perform their safety function. This should not be confused with specifications, the concept overlaps but is specific to the system/equipment performance in the context of the hazardous scenario described in the higher tier goal above.

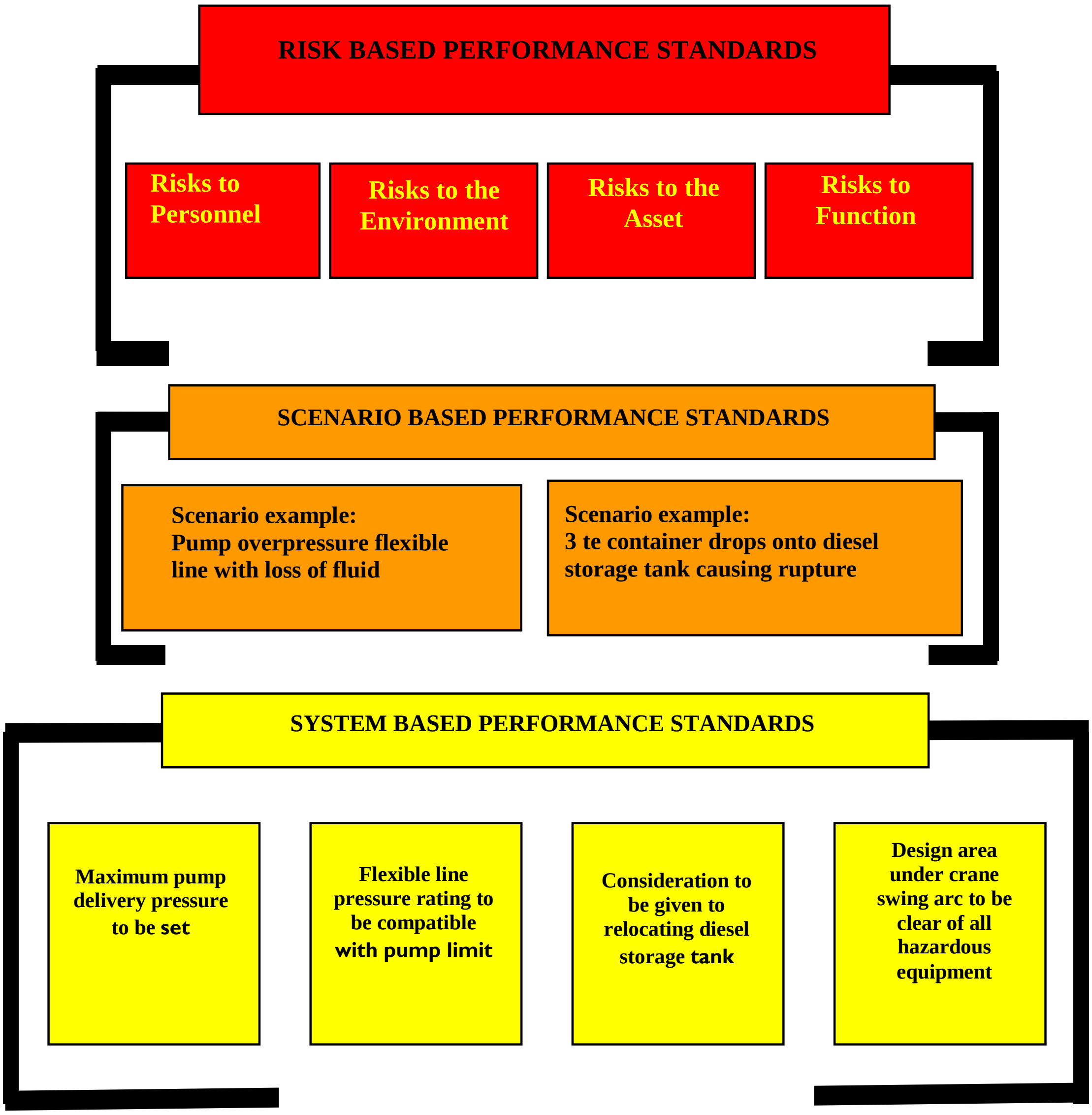

Figure 2 Risk based performance standards

Further innovations were brought into this guidance, and they are all attributes that as designers we would advocate to anyone. The guidance identified that the performance standards at systems level required certain defined characteristics to be effective. They required the following definitions:

- Functionality, defining the purpose of the system in the context of the hazard it is meant to deal with,
- Reliability/availability, defining acceptable levels of reliability and availability to be able to execute its function with an acceptable level of success,
- Survivability, defining loads from external events, e.g. heat, explosive forces, physical impacts, vibration etc. and ensuring that the systems will survive them long enough to be able to do their job.

The workgroup identified a further characteristic that has subsequently been used by some but which is difficult to measure, (where ability to be measured was identified as a key feature), this was interaction. The degree to which a system interacted with others to deal with a hazard, it is an attribute expected from safety systems but is difficult to quantify, but it should form part of the safety engineer's thinking.

This particular guidance also incorporated the use of the lifecycle; at this time the drafts of IEC 61508 (IEC, 1998) were being considered and the assessment of safety over a full lifecycle was a worthy idea. The life cycle approach has successfully been applied to project documentation. Each deliverable has a life cycle code applied to it, this clearly identifies the life cycle phase over which this information is intended to be used. This approach also assists the cataloguing and archiving of information as well as acting as a filter for the information that is important to the workforce.

Statutory Requirements for Design and Construction

The Design and Construction Regulations (HMSO, 1996) have been the most significant recent regulation and have introduced some new and crucial aspects to the management of major hazards. This regulation introduced the concept of verification to supersede certification and requires Duty Holders to define Safety Critical Elements as a major plank of their verification scheme.

The definition of Safety Critical Elements (SCEs) has not always been entirely clearly understood. The application has generally been to apply the definition to existing and obviously safety related equipment, such as fire fighting equipment and fire and gas detection. However, the key requirement is to define equipment that acts as a barrier to major event initiation and subsequent escalation. We have proposed a definition that identifies Safety Critical Elements by working through the escalation path to the defined major hazards and then populating the escalation path with equipment/actions that stop or slow the escalation in (figure 3). This logic can then be extrapolated to identify actions required for Emergency Response as well. Having identified the SCEs, the analysts and engineers can assign appropriate Performance Standards along the lines described above.

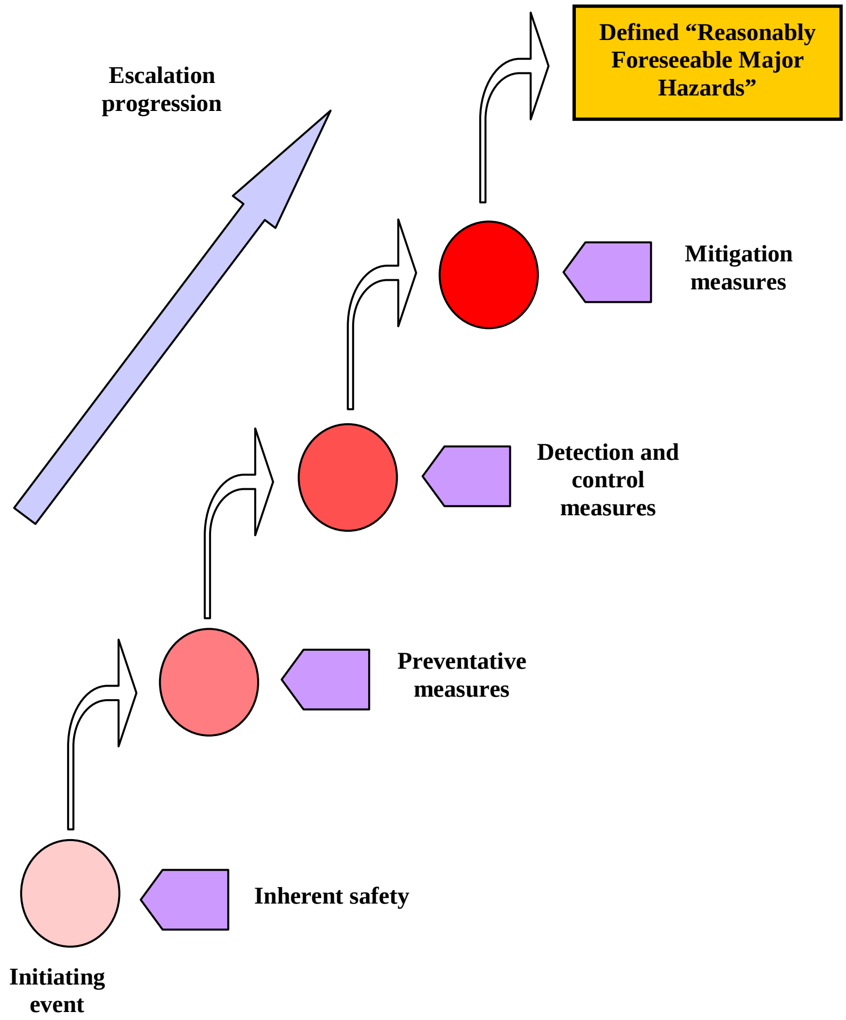

Figure 3 Escalation of safety critical elements.

The related duty of having in place a verification scheme has also highlighted some difficulties. This requires a written scheme as part of the Safety Management System to provide assurance that the SCEs have been identified, that appropriate Performance Standards have been defined for them and that they are being maintained to that defined standard.

CONCLUSIONS

The offshore industry has embraced the change from prescription to goal setting and from the author's experiences on industry committees, many are agreed that it is better. We recommend some of the tools described in this paper to help health & safety practitioners achieve these goals.

- Define Safety Critical Elements, the logical structure described in this paper noting the barriers along the escalation path will identify the less obvious elements. Stratifying them into a protective hierarchy will further aid understanding the hazard and the role the measures will play.

- The life cycle is very effective, define the Safety Critical Elements for each stage of the project life cycle (as must be the Performance Standards) and over the full life cycle, cost benefit analysis can be used to justify the safety measures.

- The Performance Standard concept, it is effectively an element of a specification, focussed on the role required for safety. Stating the attributes of function, reliability/availability and survivability provides assurance that the measures will be appropriate to their task.

- We recommend the three-tier Performance Standard structure. It has been subject to considerable debate, and although the UKOOA guidance did not explicitly describe it in the terms used in this paper, no comments used in debate have swayed the authors from considering this a logical approach.

- The application of a verification scheme which is risk based and implemented internally whilst audited externally, is difficult to set up and not always well understood. It involves many parties, including many without any specialist knowledge of safety. To work well, it requires communication, education and training. If it is used well, it can reduce external costs. However, a word of warning should be noted. Regulators are under pressure with resources and costs as much as anyone, and the verification approach allows them to implement a self-policing regime. Everyone should be prepared for this type of regime.

- Goal setting requires more sophistication, this should not be seen as an adverse effect. To be successfully applied, the local Regulator must be more sophisticated and willing to engage in discussion about the management of safety and risk, more emphasis is put on the company to develop their safety culture. Appropriate leadership and behaviour will always make safety work. On the downside, it can seen that goal setting is more difficult to implement and to police.

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BEHAVIOUR BASED IMPROVEMENT OF SAFETY AND HEALTH DURING THE CONSTRUCTION PHASE.

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ABSTRACT

The integrated chemical concern DSM acquired Veba's plastic company Vestolen in November 1997. DSM is modernising and upgrading the existing 6 plants and expanding total site capacity with a factor 3 to approximately 1 million tons by constructing 2 world scale plants with utilities and logistics.

For years, DSM has a commitment to provide a safe work-environment and a target of zero accidents. Right from the start, for the Project Team DPO with their main contractors Technip and Kvaerner, safety was a daily theme equal to other business parameters. They established an organisation and communication system based on their safety plan and be supported by a professional safety staff. Additional support came from JMJ Associates. They implemented their Incident and Injury-Free ™ methodology by carrying out a diagnostic survey, make suggestions for additional safety practices, conduct workshops for management and supervisors, and coached the foremen.
Despite the efforts, our safety performance was a concern!

Early 1999 we registered a few First Aid cases. By the end of May, we registered 5 Lost Time Accidents, 5 Restricted Work cases, 2 Medical Treatment cases and 28 First Aid cases! [1]

We were looking for answers to turn the tide!

At the peak of our Projects we counted every day about 1000 workers on site. They represented more than 45 different contractors from 16 different Nationalities. In daily conversations you could hear about 12 different languages.

Their safety was our major concern!

With a unique program of management involvement, and the commitment from the Supervisors and Foramens we were able to turn the tide. We find an effective way to chance the behaviour of all the people, chance their attitude and had a beginning of a culture change. As of February 2000 we reach a milestone of over a million man-hours. Our last Recordable accident is registered in October 1999.

INTRODUCTION

The chemical concern DSM (Heerlen NL) acquired VEBA's polymer company Vestolen (now DSM Polyolefine, DPO) at Gelsenkirchen, Germany, in November 1997. The purpose of this investment was to modernize and upgrade the existing six plants, polyethylene (PE) and polypropylene (PP) and at the same time expanding the total site capacity by a factor of 3, to approximately 1 million tons/year. To reach this goal, DSM had to construct two world scale plants for PE and PP (approx. 0.6 Mt per year) including a major logistics project and common facilities.

For many years, DSM has a commitment to providing a safe work-environment and to incident and injury free sites and plants. The motivation of course, is the well being of people, and the philosophy is, that it is the same attitude that leads to safe work and high results.

Our target in this specific project was its completion without any incidents and injury free. Along with their main Engineering Procurement Construction (EPC) contractors Technip (Paris, F) and Kvaerner (Zoetermeer, NL), the project team faced difficult challenges, e.g.

- Forty five different subcontractors on site;
- Sixteen different nationalities and at least as many corresponding cultures;
- Many different languages.
- People's attitude towards safety at the site different of what DSM and most of its contractors experienced before – "there is no safety culture" as some of them said;
- Historical statistics predicting that severe accidents would normally happen in such a project.

THE PREPARATION BEFORE THE START OF CONSTRUCTION

The expansion projects at Gelsenkirchen were estimated at approximately 500 million US$. This highest investment as well as the most extensive project in the history of DSM is guided by a highly qualified and experienced project team.

The DSM-Polyolefine project team (DPO- PT), together with Technip and Kvaerner, established a detailed Safety, Health and Environment (SHE) plan before the start of the building phase. This plan is signed off by management to give a full commitment to safety.

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This commitment with regard to safety on this site goes way beyond governmental regulations. DSM and their main contractors' management demonstrated this commitment from the beginning:

- in their participation in the Safety Steering Committee;
- in field walkthroughs;
- in the subcontractor selection and review of work and safety performance;
- in training of all personnel.

Due to prior projects with DSM, the two selected EPC contractors were familiar with DSM' s safety policies. They both have a lot of experience and have shown an excellent past safety performance. During the design phase the DSM-Polyolefine-project team carried out hazard and operability ("HAZOP") studies, while the EPC contractors have conducted Risk Analysis. They required from their subcontractors a complete Risk Analysis of their specific operations, before the start of their activities.
Their results were added to the SHE- plan.

Support is received from safety professionals that are full time on site. They advise and support the line management for a structured approach of Safety, health and environment, based on DSM's eight care elements.

THE FIRST RESULTS

In the early phase of the construction we discovered the following, which gave us a lot of concern:

- The distinction 'safety' was missing for most of the subcontractors;
- People thought that being interested in and committed to getting the job done was sufficient to guarantee good safety results. What they experienced here was a different approach to safety in their job;
- More than experienced in past projects, the daily practice showed a staged sub-subcontracting with a high turnover of people;
- Although there was no declared safety commitment from most of the subcontractors present, they showed some concern regarding their own sub-subcontractors;
- The belief in injury free work was not existing in the beginning: "Accidents normally happen"
- Many workers complied with the rules only if checks were made.

Figure 1 gives a cumulative overview of the Frequency Index (FI) for Lost Time Accidents (LTA) and Recordable Accidents (RA = LTAs + Restricted Work Cases + Medical Treatment Cases), all according to OSHA definitions.

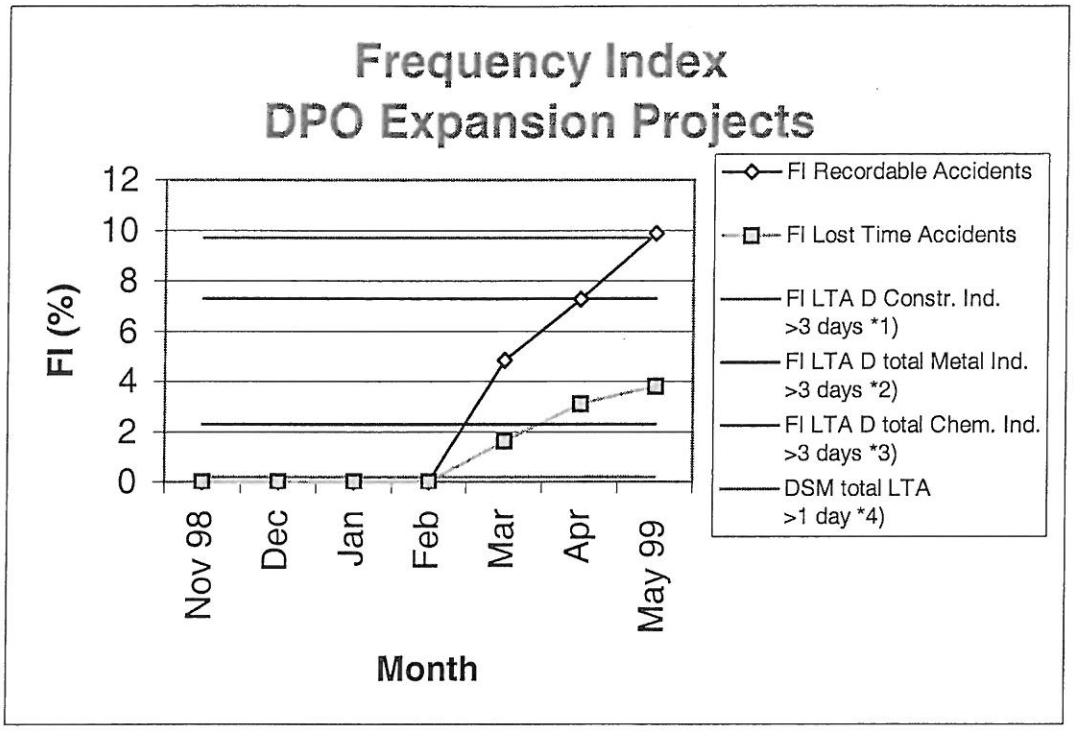

Figure 1: Despite the efforts, our safety performance was a real concern!

The Frequency Index (FI) is defined as: $\frac{\sum A * 1600 * 100}{\sum MH * 12}$

Where A=number of Recordable Accidents resp. Lost Time Accidents per month, MH= Total manhours per month, assuming 8 hours of work per day of effective workdays per month 1600= average working hours a year;100= percentage 12= months per year. DSM-Polyolefine started to calculate the FI from the start of the project in November 1998. A comparison of our results is given with regard to the German Construction-, Metal- and Chemical Industry and the DSM concern.

In early 1999 we registered only a few First Aid (FA) cases, but at the end of May, we had registered 5 LTA's, 5 Restricted Work Cases, 2 Medical Treatment Cases and 28 First Aid Cases. This clearly shows that the safety performance was on an unacceptably low level and that our initial concerns were justified.

KEY POINTS OF WHAT WAS MISSING

These initial poor results were disappointing.However, we maintained our commitment to safety and continued to strive for an injury free environment.

To improve the safety culture at the project site, we started as of March 1999 to work with JMJ Associates. A contribution to completely change the safety performance was the use of the model of The Four Worlds of Safety used by JMJ Associates. (see Figure 2)

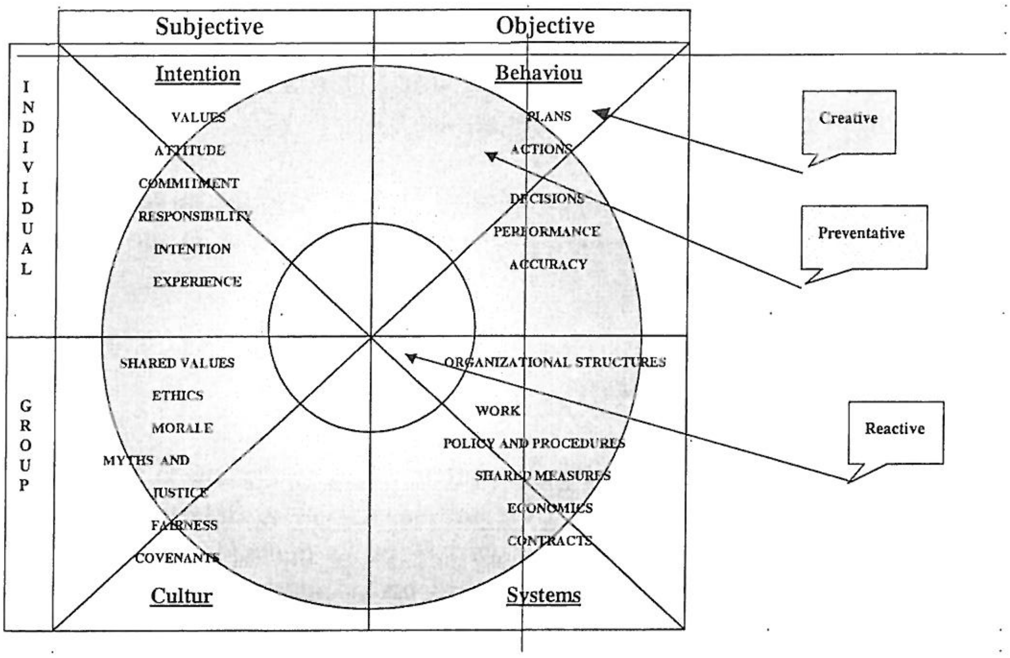

Figure 2 Map of the Four Worlds of Safety after JMJ Associates 1998.

The diagram shows four themes, where safety standards must be observed and improved from the point of view of the individual and of the group. The graphic mentiones also different sub-themes that are to be discussed whether they already are fulfilled and optimized or whether they still are missing. Creative, Preventative and Reactive are different reactions and attitudes towards safety in a company. Reactive: the company only reacts when an accident already has happened. Preventative: the company does hazard assessments and analysis on incidents to realize better personal protection of the employees as well as to prevent accidents. Creative: the company is using programs, methods and the creativity of people that help to achieve a better commitment to safety and its improvement by every single employee, foreman or manager.

Intention

The motivation behind safety on the project is to take care of people. Management and foremen (of the subcontractors) are not perceived to be proactive with regard to safety they will comply when they are told "Safety is not a priority, much less a value".

Behaviour

"Safety is reactive – if some authority says something, behaviour will be corrected, but only temporarily and continuous correction is necessary." "Construction managers and foremen do not correct many unsafe work practices." "Leadership and management (of subcontractors), don't act consistent with their commitment to safety."

Systems

"Safety practices on this project are new for some of the subcontractors – they have not been required on other jobs they did in the past"

Culture
Progress of the project is seen to be the highest priority. Safety is not part of the mindset, but the morale is good. "If safety practice will impact progress or cost, don't do it until someone tells you to". The paradigm or belief was: "This is construction. People will get hurt. It is normal. I just hope someone does not die."

These key points give a good impression of our situation. Also the in-depth analysis of the accidents endorse, that the deeper laying causes find their roots in the above described missing points.

THE ADDITIONAL ACTIONS

We started with a safety audit, a safety kick off meeting for the management of both the contractors and their subcontractors, then the launch of a Safety Leadership Team, interviews and a couple of one- or two-day workshops for managers as well as supervisors and foremen. During this first phase more accidents occured (see Fig. 1: 'Results'), but this was no reason to stop the effort. It was more a reason to increase the input in our safety program and to continue what we had started:

- In special workshops (JMJ) all managers of DSM-Polyolefine, Technip, Kvaerner and all construction contractors had a training in "incident and injury-free";
- Project-team members and foremen from the construction contractors followed a special workshop about how to deal with safety on site. The injury-free principal was an important item in these workshops;
- Common safety problems and possible risks were discussed during daily discussions between foremen and personnel (Pre-task meetings);
- Safety-inspections were organized on a daily basis. Employees from DSM-Polyolefine, Kvaerner or Technip and construction contractors together went on site to check their safety performance;
- On a weekly basis toolbox meetings were held by all construction sub-contractors;
- Management of all construction sub-contractors have gone on site to get information about their own safety performance;
- In addition to the safety instruction on the first day of arrival supplementary safety trainings like, for example, (Safety Training Observation Program (STOP) workshops, were organized;
- Several periodic meetings (weekly) were held to monitor agreed actions and to discuss preventive actions;
- Safety items were promoted by posters, flyers and banners with safety slogans (in several languages).
- A Safety Leadership Team (top management) of DPO and EPC contractors to set policy and priorities (once a month)
- A safety coordination between safety officers of DSM, EPC contractors and sub-contractors

Some of the above actions described are measured and handled in a structured way as so called Input Indicators as shown in Figure 3.

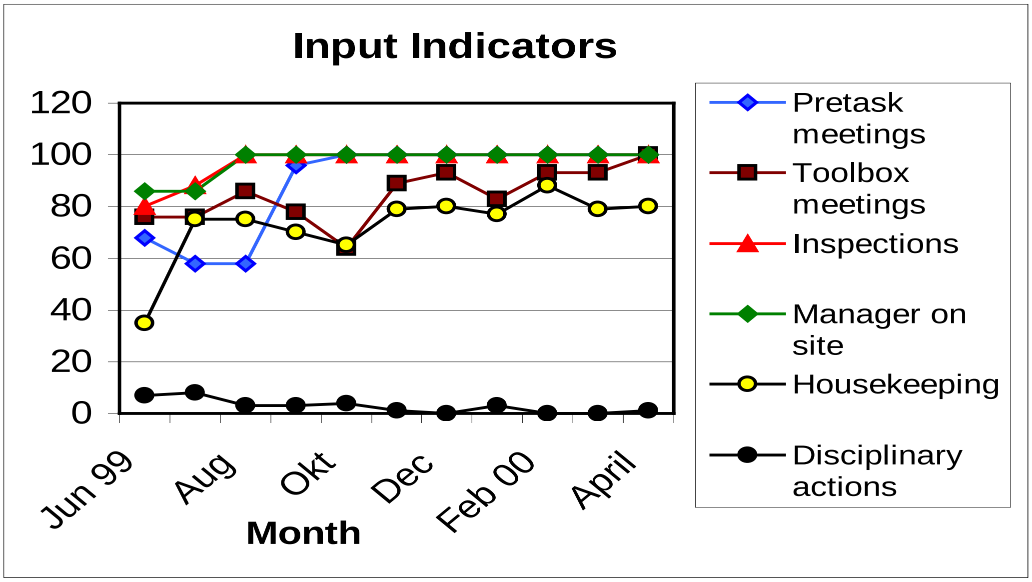

Fig. 3: Input Indicators in % and Disciplinary actions in absolute numbers.

The input indicators are instruments the company uses to monitor the implementation of actions agreed upon. Figures are expressed as a percentage of the maximum (100%). Housekeeping is one of the most important observation subjects during the safety inspections made by management and safety officers.

The difficulty was not training the management, supervisors, foremen etc. in the understanding of incidents and injury free, but the translation from theory to practical work on site.

The people on site had to understand that safety is not about numbers and statistics. It is about people. This is one of the main messages in the DSM Safety Policy. The other important message for them was that every accident can be avoided. This was the main driver for all the people who made this change, not only for the management of the sub-contractors, but also for the supervisors and superintendents of the Engineering procurement contractors. All had taken their commitment seriously and trained everybody where necessary through the whole project.
The safety staff supported these people in talking about safety, training and coaching the people and demanding safe behaviour. They stimulated everybody to commit themselves to safe work practices that people follow in their daily actions. And this is how it finally turned out.

RESULTS

The history of the project shows that our initial concerns regarding the safety performance of the subcontractors has been legitimate. Until May 99 after only 200,000 man-hours of construction work 13 recordable accidents (five with lost time) were registered. This was not an expression of our commitment to safety. Although these statistics were within the range of the German construction industry figures, this was completely unacceptable. If the initial safety performance of our project would go on in this way, while the majority of the work had not even started, the project would attain an undesirable historical record in view of DSM's safety standards.

The programs we described in this paper led to a continuous improvement of the safety performance:

- In the period from July until October seven recordable accidents happened (three of them with lost time);
- The last Recordable Accident was registered on October, 5th 1999;
- The last Lost Time Accident was registered on September, 7th 1999;
- In total 1.4 million manhours were spent;
- In the Kvaerner project (total 400,000 manhours) no Recordable Accidents were registered;
- In the Technip projects (total 1 million manhours) the 600,000 manhours were without Recordable Accidents.

As the results in Figure 4 show, with this unique program of management involvement and the commitment from the supervisors and foremen we were able to turn the tide.

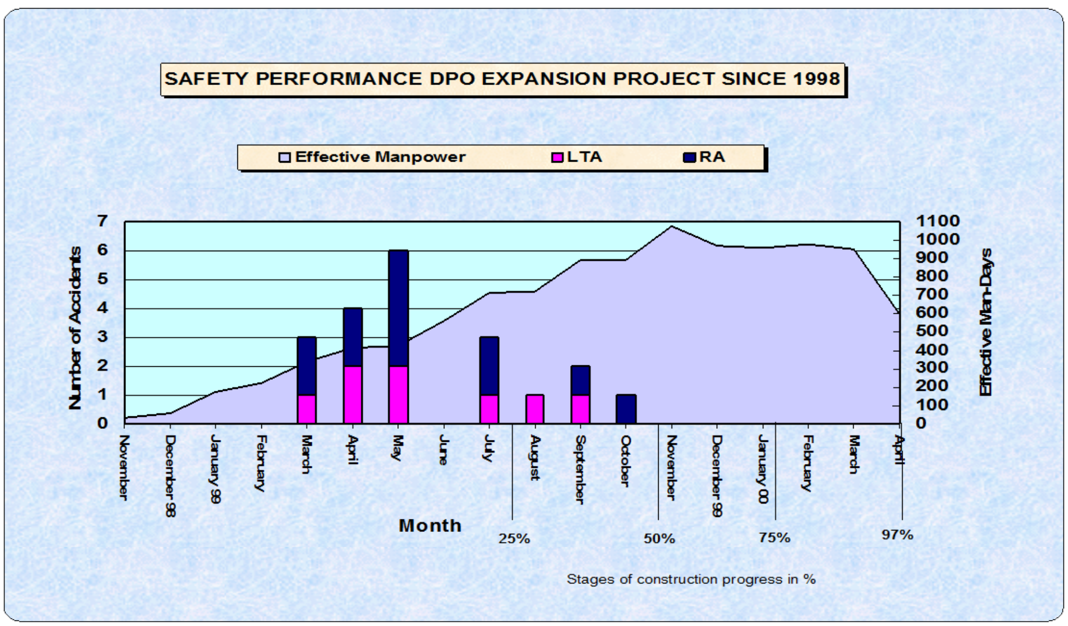

Figure 4: Safety Performance DSM-Polyolefine Expansion Projects since November 1998.

The diagram Fig. 4 gives an overview over the development of manpower and the number of Recordable accidents, RA and Lost time accidents, LTA from the start of the construction in November 1998 till the month April 2000, where the new production plants are nearly finished.

The effective Man- Days are defined as $\frac{MH*12}{1600}$ *with MH= number of manhours per month.*

Knowing that nobody wants to get hurt, we communicated to the employees that ‘Incident and Injury Free’ was for the management the highest goal. As you can see we found a way to change the behaviour of the people, change their attitude, and we achieved the beginning of a culture change at the project site. Finally, after a troubled start and with a lot of setbacks, it was people’s joint commitment as well as the management’s commitment for an injury free work environment that has come together.

IN CONCLUSION

The conditions for a quick improvement of the safety performance and for suitable success on the long run are:

1. Knowledge of, and sufficient experience with a good Safety, Health and Environment (SHE) structure.
2. Management’s unceasing and visible commitment to safety, observed by the foremen and adopted by them;
3. Support of capable and experienced safety experts;
4. Motivation of middle management and intensive inspections;.
5. The establishing of a change of behaviour to attitude and to culture, using a concept (JMJ model) and supported by workshops;
6. The drive to improve continuously, till the end.

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THE INFLUENCE OF DESIGN ON CONSTRUCTION ERGONOMICS : MANAGEMENT AND WORKER PERCEPTIONS

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ABSTRACT

Construction is by its very nature a problem in ergonomics requiring work above head height and below waist level. Construction materials are necessarily heavy and by virtue of shape and/or form may not engender lifting and handling.

Design occurs upstream of construction and consequently designers influence ergonomics directly through: design in general; selection of type of structural frame; detail; method of fixing, and specification. Various interventions, inter alia, prefabrication, precasting, preassembly and sheet or membrane type materials lessen the impact of the construction process on the human body.

Given the aforementioned, research was conducted among general contractors (GCs), representing managers, and workers in South Africa to determine the impact of construction, and consequently design, in terms of ergonomics.

According to managers and workers: repetitive movements, climbing and descending, and use of body force predominate among ergonomic related problems experienced; excavating, formwork and concreting predominate among trades representing an ergonomic problem; materials handling predominates among ergonomic aspects requiring attention, and awareness and safe work procedures (SWPs) predominate among interventions which can contribute to an improvement in ergonomics.

Keywords: Construction, design, ergonomics

LITERATURE SURVEY

Introduction

According to La Dou (1994) ergonomics (from the Greek ergon, ‘to work’, and nomos, ‘study of’) is literally the study of work, or the work system, including the worker, his or her tools, and his or her workplace. He states that “it is an applied science concerned with people’s characteristics that need to be considered in designing and arranging things that they use in order that people and things will interact most effectively and safely.”

The Center to Protect Workers' Rights (CPWR) (1998) cites statistics provided by the US Bureau of Labor Statistics. The rate of sprains and strains in construction – 1.6 per 100 full-time equivalent workers – is the second highest of all industries. Sprains and strains (38%) predominated in terms of the nature of injuries and illness resulting in days away from work. The rate of back injuries in construction – 1 per 100 full-time equivalent workers – is the second highest of all industries. The back (23.7%) predominated in terms of anatomic region affected by non-fatal injuries.

Ergonomic problems

Based upon a score out of 10, research conducted among six trades in the USA determined the following to be the top five ergonomic problems: working in the same position for long periods (5.67); bending or twisting the back in an awkward way (5.46); working in awkward or cramped positions (5.00); working when injured or hurt (4.69), and handling heavy materials or equipment (4.63) (Zimmerman et al., 1997).

Ergonomic problems and design related decisions

Schneider and Susi (1994) reviewed the findings of a team of industrial hygienists who followed the construction of a four-storey office building for the 15-month duration of the project. Relative to trades, the following examples are a summary and provide an indication of the ergonomic hazards which result from the construction process and design related solutions.

Concreting: Shovelling and smoothing the surface of concrete is strenuous on the lower back. The addition of plasticisers improves concrete workability.

Reinforcing: The fixing and tying of bar reinforcing requires bending and a great deal of rapid repetitive twisting of the wrist, the latter resulting in the development of ganglion cysts. The use of fabric in lieu of bar reinforcing reduces the amount of time spent fixing and tying reinforcing per concrete element, and the amount of bending and rapid repetitive twisting of the wrist.

Formwork: The erection and striking of supportwork and formwork requires a large amount of bending, twisting and body force. Designers can facilitate the use of composite systems through the simplification of design, inter alia, table forms and wall forms which can be handled by cranage, thereby reducing the manual content of an activity. The use of precast concrete also reduces the amount of supportwork and formwork and on-site fixing and tying of reinforcing required. Prestressed concrete elements, particularly slabs, also reduced the amount of bar reinforcing.

Structural steelwork: Ergonomic problems relating to the erection thereof include awkward postures, occasional high force requirements, static postures, repetitive movements, use of pneumatic tools and lifting. The high risk nature of the activity which entails, inter alia, straddling beams several feet in the air while aligning and bolting together columns and beams, compounds the problems. Preassembly, simplified joints and integral safety features can reduce the hazards.

Masonry: Block and brick laying represents major ergonomic hazards to workers. Lifting an average of 1000 bricks a day is the equivalent to lifting 2300 – 4000kg, and 1000 trunk-twist flexions. Design improvements include the incorporation of hand holds in blocks to facilitate lifting. Alternative wall systems constitute the optimum solution.

Roofing: Roofing poses many different ergonomic hazards, but primarily materials handling. Of the three types of roofing, unit and sheet materials and waterproofing membranes, unit materials require considerably more bending, twisting and handling of mass per square metre of covered area, than sheet materials.

Building fabric: Differing systems and materials pose differing ergonomic problems. Concrete surface finishes such as bush-hammering present a risk of hand-arm vibration and health problems such as silicosis. Natural stone claddings require a lot of lifting and hoisting of panels, adopting of awkward postures and hand-arm vibration as a result of fixing, presenting a risk of back injury and hand/wrist problems. Design alternatives include light weight sheet metal claddings and curtain walling.

Plumbing and drainage/pipefitting: Piping is often at odd angles and in cramped spaces. Specific piping materials have specific jointing methods, not all of which are complementary to ergonomics. A number of installations are suspended and require extensive overhead work, the fixing of the suspension hangers resulting in substantial stretching and twisting and consequently a high level of stress on the neck and shoulders of workers. Designers should consider the ergonomic implications of jointing methods when specifying materials, the feasibility of prefabricated stacks, and horizontal and vertical service ducts for piping.

Electrical: Electricians often work in cramped postures and their work entails a large amount of wrist action resulting in stress on the arm and shoulders. Making connections requires extensive use of hand tools, often in cramped spaces such as ceilings above and between ducting and other piping. Designers should make adequate provision for access during both design, and coordination of services during design.

Floor finishes: All floor finishes require constant kneeling and bending. Ceramic and similar tile and terrazzo work entail additional risk. Often the weight of the tiles to be set can be substantial, particularly if natural stone. Terrazzo and similar finishes require considerable hand and wrist motion. When specifying finishes designers should consider the nature of processes pertaining thereto.

Suspended ceilings: Most suspended ceilings require significant overhead work although the components are not particularly heavy. It is necessary to suspend primary tracks from hangers and secondary tracks between the primary tracks. Screw-up suspended ceilings require considerably more overhead work than lay-in tile ceilings. Consequently designers should specify the latter where possible.

Painting and decorating: Overhead painting of ceilings places considerable stress on the arms and shoulders as well as the neck. Designers should consider self-finishes where possible.

Paving and other external work: Brick paving requires work similar to that of tiling. In addition, pavers often have to be cut with an electrically powered masonry saw which requires working at ground level, and consequently bending. Although asphalt paving exposes workers to whole-body and hand-arm vibration, workers are not exposed to the volume of repetitive movements and other work related postures as in the case of brick paving.

RESEARCH

A research project conducted in South Africa, ‘Ergonomics in construction’, investigated the perceptions of construction management and workers with respect to ergonomics.

85 GCs who were either members of the Building Industries Federation South Africa (BIFSA) or the South African Federation of Civil Engineering Contractors (SAFCEC), representing management, responded to a national postal survey, which constituted a response rate of 7.1%.

122 Workers were interviewed using a structured questionnaire. Given that fourth and fifth year construction management students interviewed workers in the employ of their employers, the sample frame is best described as a convenience sample.

Commercial (69%) predominated among the types of construction GCs undertook, followed by industrial (64.3%) and domestic (45.2%). 45.2% of GCs worked mostly in the ‘0-2 floors’ height category, followed by ‘ground’ (26.2%), and ‘0-10 floors’ (17.9%). On average the GCs subcontracted out 15.8% of the value of construction on a ‘labour only’ basis and 29.8% on a ‘full’ basis. The mean number of permanent and temporary workers employed by GCs was 143.8 and 66 respectively, the mean total being 209.8

Of the 122 workers included in the analysis, 38.5% were general workers, 29.5% artisans and 21.3% semi-skilled. The mean age was 37 and the median 35 years, the youngest worker being 18 years and the oldest being 65 years of age. 41% of workers were in the 30-39 year age group. On average the workers had worked 13.6 years in construction and 6.1 years for their current employer, the median being 11.5 and 4 years respectively. 55.7% of workers worked for GCs and 36.9% for ‘full’ subcontractors. Domestic (40.5%) and commercial (28.1%) predominated among the types of construction worked in, followed by industrial (19.1%).

Table 1 presents the top nine of a total of eighteen ergonomic problems based on the daily, weekly, fortnightly, monthly or non-exposure thereto. Given the possible range of responses in terms of frequency, an importance index (II) with a maximum of four and a minimum of zero, was computed to enable ranking of the problems. It is notable that in all cases the ‘workers’ II is higher than the ‘management’ II. Given the range of the II, it is also notable that with the exception of bending, or twisting the back, all the management', 'worker' and 'overall' IIs are above the midpoint of 2.00, implying that all nine problems can be regarded as prevalent.

	Importance Index					
	Management		Worker		Overall	
Problem	**I I**	**Ranking**	**I I**	**Ranking**	**I I**	**Ranking**
Bending or twisting the back	1.96	11	3.47	2	2.72	7
Reaching away from the body	2.41	8	3.19	3	2.80	4=
Reaching overhead	2.61	6	2.99	5	2.80	4=
Repetitive movements	3.29	1	3.56	1	3.43	1
Handling heavy materials	2.63	4=	2.68	10=	2.66	8
Use of body force	2.80	3	2.82	8	2.81	3
Working in hot conditions	2.29	9	2.68	10=	2.49	9
Exposure to noise	2.54	7	2.93	6	2.74	6
Climbing and descending	2.88	2	3.01	4	2.95	2

Table 1: Top nine ranked ergonomic problem based upon management and worker perceptions.

GCs were asked to what degree twenty three trades represented a problem. Table 2 presents the top nine trades based on the frequency of 'major', 'moderate', 'minor' or 'not' responses thereto. An II with a maximum of three and a minimum of zero enabled ranking of the trades. It is notable that all the values in Table 2 are below the midpoint of 1.50, which indicates that in terms of prevalence the trades do not constitute a significant problem.

Trade	**I I**	**Ranking**
Excavating	1.46	1
Formwork	1.33	2
Concreting	1.32	3
Roofing	1.31	4
Plant operating	1.29	5
Steel erecting	1.15	6=
Screeding	1.15	6=
Bricklaying	1.13	8=
Ceiling erecting	1.13	8=

Table 2: Top nine ranked trades which represent an ergonomic problem according to management.

GCs and workers were asked to identify ergonomic related aspects which required attention. Based upon an 'overall' average response, materials handling achieved a ranking of first, followed by working platforms, housekeeping, means of ascending/descending, and materials storage (Table 3). It is notable that the response relative to workers is higher than that relative to management for all aspects.

Designers influence materials directly in that they evolve the design concept, select the type of frame and fabric, undertake the design, prepare details and specify materials.

Designers influence materials handling and mechanisation directly through the conceptual design, choice of structure, design in general, details, and specification of materials. The mass, volume, surface area, texture, edges, contents and type affect the manner in which materials are handled. The characteristics of materials, along with configuration, affect the suitability of elements and components to be mechanically handled. The characteristics of materials affect materials storage requirements and housekeeping. Site coverage affects the availability of space for materials' storage, circulation paths and roads. The type of building fabric and finishes affects the nature of, and demand for means of ascending/descending, walkways and working platforms.

Aspect	**Management**		**Workers**		**Overall**	
	Rank-ing	**Yes response (%)**	**Rank-ing**	**Yes response (%)**	**Rank-ing**	**Yes response (%)**
Circulation paths	8	53.2	8	41.3	8	47.3
Circulation roads	9	51.3	9	37.2	9	44.3
Means of ascending/descending	1	83.8	5=	65.6	4	74.7
Walkways	6	71.8	5=	65.6	6	68.7
Working platforms	2	81.7	3	70.5	2	76.1
Materials handling	3=	78.8	1	76.3	1	77.6
Materials storage	5	74.1	4	69.7	5	71.9
Mechanisation	7	64.9	7	50.4	7	57.7
Housekeeping	3=	78.8	2	70.8	3	74.8

Table 3: Ergonomic related aspects which require attention according to management and workers.

Table 4 indicates that with the exception of reengineering the process, the majority of GCs responded in the affirmative with respect to various interventions which can contribute to an improvement in ergonomics. Five of the interventions are of direct relevance to designers of structures, two are of indirect relevance and three should be considered.

Intervention	**Ranking**	**Response**			
		Yes	**No**	**Don't know**	**Total**
Awareness	1=	97.6	2.4	0.0	100.0
Design of tools	5	68.8	20.8	10.4	100.0
Design of equipment	4	75.3	16.9	7.8	100.0
Workshops on site	6	66.2	22.1	11.7	100.0
Planning	3	94.0	3.6	2.4	100.0
SWPs	1=	97.6	1.2	1.2	100.0
Design of buildings/structures	7	64.9	20.8	14.3	100.0
Details of buildings/structures	9	63.2	22.4	14.4	100.0
Specification of materials	8	64.0	26.7	9.3	100.0
Reengineering the process	10	55.7	24.3	20.0	100.0

Table 4: Interventions which can contribute to an improvement in ergonomics according to management.

Designers need to be aware of ergonomics to be able to contribute to an improvement thereof. Designers directly influence the design of buildings/structures, details of buildings/structures, the specification of materials, and can initiate the reengineering of the construction process. Although only 55.7% of GCs responded in the affirmative with respect to reengineering the process, 20% did not know.

The completeness of design, detail and specification upon commencement of construction affects the ability of contractors to plan and the availability of SWPs.

Designers should also consider the availability and current design of tools and equipment when designing, detailing and specifying. Site coverage affects the availability of space for, inter alia, workshops on site.

With the exception of legislation (17.3%), most GCs responded that relative to ergonomics there should be more: awareness (85.5%); education (83.3%); training (83.3%), and focus (75%).

60.7% of GCs responded that health and safety is ‘very important’ and 32.1% ‘important’.

29.4% of GCs and 13.9% of workers had a comment, and 2.5% of workers had two or more comments regarding ergonomics/health and safety. GC comments were general in nature. Selected ergonomics related responses include: “Safety and constructability must be taken into account when architects and clients design buildings”; “Ergonomics is a way to improve and make the job more comfortable and safer for employees” and “Better ergonomics will reduce fatigue and stress and will/should increase productivity.”

Most worker comments pertained to the lack of provision of PPE. Selected ergonomic related responses include: “Depends on use of mechanical equipment”; “Better sequencing of operations”, and “Workplace can get congested, require more space sometimes.”

CONCLUSIONS

Construction is a physically demanding process resulting in the exposure of workers to numerous ergonomic problems, certain trades representing more of a problem than others. However, design impacts on construction ergonomics, both directly and indirectly. Directly through: conceptual design; selection of type of structural frame and walling; detailed design, and specification of finishes and materials. Indirectly through: completeness of design at the tendering stage and upon commencement of construction; coordination of design, particularly services; site coverage; access to site; compatibility of the design to mechanisation, and the nature of the required work processes and temporary access.

RECOMMENDATIONS

The design related professions should raise the level of awareness relative to ergonomics.

Ergonomics, including health & safety, should be included in the curricula of tertiary design education.

Designers should endeavour to realise completeness of design at tendering stage.

Designers should conduct constructability reviews with specific reference to ergonomics and consider ergonomics throughout all stages of the design process.

Designers should endeavour to: maximise the degree of preassembly, prefabrication and the use of precast components; facilitate the use of composite supportwork and formwork systems, and opt for membrane type wall systems.

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THE HOLISTIC INFLUENCE OF DESIGN ON CONSTRUCTION HEALTH AND SAFETY (H&S): GENERAL CONTRACTOR (GC) PERCEPTIONS

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ABSTRACT

Construction H&S occurs, or does not occur downstream of clients and designers.

Designers influence construction H&S, directly and indirectly. Directly, through design specific, supervisory and administrative interventions. Design specific interventions include: general design; detail; method of fixing, and specification of materials and finishes. Supervisory and administrative interventions include: reference to H&S upon site handover, and during site visits and inspections; inclusion of H&S as an agenda item during site meetings, and the requiring of H&S reporting by contractors.

Indirectly through type of procurement system used, pre-qualification, project schedule, partnering and the facilitating of pre-planning.

Given the aforementioned, South African general contractors (GCs) were surveyed to determine their perceptions regarding the holistic influence of design on construction and needs related thereto. The salient findings include: H&S is negatively affected by short project periods and competitive tendering; there should be pre-qualification on H&S; there should be a provisional sum for H&S; GCs require and use various media to pre-plan H&S; design and method of fixing predominate among aspects which negatively affect H&S and designers should receive H&S education at tertiary level.

The findings amplify the need for: the inclusion of H&S as a project parameter, along with cost, quality and schedule; the consideration of and reference to H&S by designers on all occasions throughout all phases of a project, and a holistic approach to H&S by designers.

Keywords: Construction, design, health and safety, holistic influence

LITERATURE SURVEY

Introduction

Various authors have documented and raised the level of awareness with respect to the influence of design on health and safety (H&S), inter alia, Hinze (1997) and Jeffrey and Douglas (1994). However, the International Labour Office (ILO) (1992) specifically states that designers should: receive training in H&S; integrate the H&S of construction workers into the design and planning process; not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials, and take into account the H&S of workers during subsequent maintenance.

However, the influence of design is not limited to design per se. The design function often includes advising clients with respect to the type of procurement system (PS) and form of contract to be used, the selecting of a contractor, including pre-qualifying, and the project duration. Designers also participate in partnering and can facilitate the pre-planning of H&S through completeness of design. Given the aforementioned, the term and keyword 'holistic influence' has been used.

Further, given that clients invariably appoint designers or project managers as the principal agent (PA), the specific ILO (1992) recommendations relative to clients should be noted. These are that clients should: coordinate or nominate a competent person to coordinate all activities relating to health and safety; inform all contractors of special risks to H&S of which they are or should be aware; require contractors submitting tenders to make provision for H&S, and consider H&S requirements when estimating dates for stage and overall completion of the project.

Motivation

The cost of accidents (COA) is frequently cited as a major motivation for addressing H&S (Hinze, 1997; Levitt & Samelson, 1993). Research indicates the total COA to constitute 6.5% of the value of completed construction (The Business Roundtable, 1991) and approximately 8.5% of tender price (Anderson, 1997). A further motivation is the synergy between H&S and other project parameters of: cost; environment; productivity; quality, and schedule (Smallwood, 1996).

Legislation

Section 10 of the South African Occupational Health & Safety Act (OH&S Act) (Republic of South Africa, 1993) allocates responsibility to designers to ensure that any 'article' is safe and without risks to health.

The South African 'Draft Construction Regulations' (Department of Labour, 2000) schedule important requirements with respect to clients and designers. Clients shall, inter alia: allow sufficient time for the completion of projects; pre-qualify contractors; conduct periodic audits of the contractors' H&S performance, and ensure that where design changes are made sufficient H&S information is provided to the contractors. Designers shall, inter alia: make available all relevant information about the design such as the soil investigation report, design loadings of the structure, and methods and sequence of construction, and inform the principle contractors of any known or anticipated dangers or hazards or special measures required for the safe execution of the works.

Influence of design

The overall design, manifested in shape of the structure, configuration on plan, type of structural frame and enclosing fabric, influence H&S (Hinze & Gambatese, 1994). Jeffrey & Douglas (1994) cite research conducted in Europe, which determined that of site fatalities, 35% were caused by falls, which could have been reduced through design decisions.

Detail and method of fixing may require bending or twisting the back in an awkward way; working in awkward or cramped positions, reaching away from the body; reaching overhead; repetitive movements, and use of body force (Schneider & Susi, 1994). According to Schneider & Susi (1994) materials may be heavy and present manual materials handling problems.

Jeffrey & Douglas (1994) also advocate optimal interaction with clients at the design brief stage, as deviations from it at a later stage result in variation orders (VOs) which can be the catalyst that trigger a series of events from designer through to workers that culminate in an accident on site.

'Design for safe construction' is one of sixteen constructability design principles listed by Adams & Ferguson (McGeorge & Palmer, 1997). However, most of the other fifteen principles are indirectly related to, and consequently influence H&S.

Procurement

Rwelamila & Smallwood (1999) say evidence gathered suggests incorrect choice and use of PSs has contributed to neglecting of H&S by project stakeholders. Dreger (1996) concurs and says the form of construction delivery affects contractual relationships and the development of mutual goals.

Research conducted in South Africa determined the traditional construction procurement system (TCPS) to dominate among PSs used (Rwelamila & Smallwood, 1999). The TCPS follows a sequence of four phases: preparation; design; preparing and obtaining tenders, and construction. Ideally, design is complete when preparing bills of quantities. However, invariably an optimum design brief is not realised, a bill of quantities or schedule of rates is evolved from the partially complete design and details, resulting in 'provisional' quantities and a plethora of prime cost and provisional sums. Further, a contractor is appointed primarily on the basis of 'lowest cost' and commences work on site shortly after having been awarded the contract, having very little knowledge of the structure to be erected. Other findings include that clients are not familiar with other PSs and that the designers do not raise the choice of procurement method as an issue.

Meere (1990) advocates the integration of design and construction as a contribution to improving H&S. Dreger (1996) concurs and recommends the design-build contract form as the integration of design and construction has the greatest potential for success as it creates common project goals.

Current references to H&S in standard South African contract documentation are generally indirect, hardly coercive, and depending upon the level of commitment, contractors address H&S to varying degrees (Smallwood & Rwelamila, 1996).

According to Smallwood (1996) market conditions in South Africa are such that contractors frequently find themsleves in the iniquitous position that should they make the requisite allowances for H&S, they run the risk of losing the tender or negotiations to a competitor who is less committed in terms of H&S. Fryer (1997) maintains that for construction to become healthier and safer will require clients to accept that there is a 'H&S premium' to pay in construction; that if getting a rock-bottom price means that people will be killed or seriously injured, then the price is too low.

The design of a project is a great influence on determining the method of construction and the requisite H&S interventions (Liska, 1994). Consequently, sufficient design related information needs to be available at pre-project stage to facilitate budgeting for adequate resources. Research conducted in Australia determined that drawings, legislation and site inspections are the sources of information most frequently consulted for H&S planning (Oluwoye & MacLennan, 1994).

Levitt & Samelson (1993) recommend that clients pre-qualify contractors on H&S criteria as pre-qualification provides a standardised method for selecting contractors on the basis of demonstrated safe work records, H&S commitment and knowledge, and the ability to work in a healthy and safe manner.

Partnering brings the various stakeholders in a project together, designers included, to develop mutual goals and mechanisms for solving problems. Partnering complements H&S for two reasons. First, the improvement in all-round relations on the project, which in turn according to research results in reduced accidents. Second, the performance objectives which form part of the partnering charter usually include a specific mention of H&S (Levitt & Samelson, 1993).

Shortened contract periods result in a disproportionate increase in the amount of resources introduced into the workplace and the possible non-sequential execution of activities (Smallwood, 1996). Hinze (1997) cites pressure to meet unrealistic deadlines as a common source of mental diversion, which diversion increases the susceptibility of injury.

RESEARCH

71 Metropolitan area based GC members of two South African contractor associations responded to a national postal survey, realising a response rate of 28.2%.

Commercial (70.4%) and industrial (70.4%) predominated among the types of construction GCs undertook, followed by domestic (35.2%) and infrastructure (16.9%).

43.7% of GCs worked mostly in the '0-2 floors' height category, followed by ground (26.8%), and '0-10 floors' (22.5%).

On average the GCs subcontracted out 39.8% of the value of construction, the median being 40%, the minimum 0%, and the maximum 90%. The GCs employed on average 351.5 workers, the median being 150, the minimum 0 and the maximum 3130.

49.3% of GCs responded that H&S is 'very important' and 40.8% 'important'.

Table 1 indicates that site inspection predominated among references used by GCs when deliberating/pricing H&S during tendering, followed by drawings, specification and geotechnical reports. It is notable that more than one GC endorsed their questionnaire: "Models are never available!" possibly implying that should they be available, they would be referred to. A possible reason for the infrequent use of schedules is the availability of information pertaining to materials in specifications and bill of quantities. However, schedules are not necessarily available at tendering stage.

Given the inherent risks of excavating and excavation related fatalities world wide, then geotechnical reports should always be available and referred to at tendering stage.

Reference	**Yes response (%)**
Site inspection	69.0
Drawings	59.2
Specification	46.5
Geotechnical reports	26.8
Schedules	11.3
Model	2.8

Table 1: References used by GCs when deliberating/pricing H&S during tendering.

56.3% of GCs responded that H&S is negatively affected by short project periods. 29.6% responded in the negative. Table 2 indicates that general pressure, less time per activity and more workers predominated among the ways in which H&S is negatively affected by short project period.

Aspect	**Yes response (%)**
General pressure	67.5
Less time per activity	65.0
More workers	57.5
Overtime	40.0
More subcontractors	35.0
Inadequate information	35.0
Variations	27.5
More plant	25.0

Table 2: Ways in which health and safety are negatively affected by short project period according to GCs.

68.2% of GCs responded that H&S is negatively affected by competitive tendering. 31.8% responded in the negative.

58.6% of GCs responded that contractors should be pre-qualified on H&S. 31.4% responded in the negative.

59.2% of GCs responded that there should be a provisional sum for H&S. 32.4% responded in the negative.

GCs were requested to select from a series of design/factors, those which can negatively affect H&S. Consequently the percentage 'No' and 'Don't know' responses cannot be qualified. Design (general) and method of fixing predominated, followed relatively closely by content of material, mass of material, size of material and edge of material (Table 3). Position of components and other aspects/factors were identified by less than one-third of GCs.

Aspect/Factor	**Yes response (%)**
Design (general)	50.0
Method of fixing	47.1
Content of material	38.6
Mass of material	38.6
Size of material	37.1
Edge of material	35.7
Position of components	28.6
Surface of material	27.1
Details	17.1
Area of components	14.3

Table 3: Design aspects/factors which can negatively affect health and safety according to GCs.

Table 4 indicates the extent to which architects, engineers, project managers (PMs) and clients made reference to health and safety on various occasions based on the frequency of reference thereto: always; sometimes; never, and don't know. Given the possible range of responses in terms of frequency, an importance index (II), with a maximum of two and a minimum of zero, was computed to enable ranking of the stakeholders. Given the range of the II, it is notable that with the exception of two occasions relative to PMs (*), all the II values are below the midpoint of 1.00, implying that reference to health and safety cannot be regarded as prevalent.

A focused appreciation is facilitated by the overall ranking of reference to H&S on each occasion per stakeholders, the computation of an average II for the occasions per stakeholder, and the computation of an average II for the stakeholders per occasion.

In terms of an average II per stakeholder , PMs are credited with the most frequent reference to H&S, followed by engineers, architects and clients. The perceived focus on H&S by PMs is probably attributable to their 'managerial' approach and likely appreciation of the holistic role of H&S in overall project performance. The perceived focus by engineers is probably attributable to their specific design role, and in cases, their responsibility for H&S in terms of certain general conditions of contract.

Site meeting is ranked first, general discussion second, and site handover and site inspection joint third, in terms of an average II per occasion.

Stakeholder	Occasion									
	Site handover		Site inspection		Site meeting		General discussion		Average	
	II	Ranking	II	Ranking	II	Ranking	II	Ranking	II	Ranking
Architect	0.69	16	0.81	11=	0.92	5	0.81	11=	0.81	3
Engineer	0.86	7=	0.89	6	0.98	3	0.86	7=	0.90	2
PM	1.00*	2	0.79	13	1.12*	1	0.97	4	0.97	1
Client	0.77	14=	0.83	9=	0.83	9=	0.77	14=	0.80	4
Average	0.83	3=	0.83	3=	0.96	1	0.85	2	-	-

Table 4: Frequency of reference to H&S by architects, engineers, PMs and clients on various occasions in terms of IIs and rankings according to GCs.

Most GCs responded that architects and engineers/designers should receive H&S education at technikons (polytechnics) and universities (Table 5).

Designer	Yes response (%) per institution	
	Technikon	University
Architect	87.0	87.0
Engineer/Designer	90.0	89.9

Table 5 : Need for H&S education for architects and engineers/designers according to GCs.

47.9% of GCs had comments regarding the role of architects and engineers/designers in H&S. Selected comments include: “They should be fully aware of safety requirements and should assist in compliance of the OH&S Act.”; “Practical safety requirements must be taken into consideration when designing the structure…”; “It is very important for consultants to be aware when specifying contract period, types of materials, etc.”, and “H&S should form part of the contract, priced item for item in the bills, enforced as are sheds, plants, etc.”

CONCLUSIONS

Given that the findings are based upon GC management perceptions, as opposed to observations, and that designers were not surveyed, it could be said that the findings are biased. However, given that GCs undertake the work, they are the stakeholder best suited to comment on the holistic influence of design on construction H&S.

Designers can positively influence H&S, both directly and indirectly. Directly through design per se, and supervisory and administrative interventions.

Design related interventions include: general design; detail; method of fixing, and specification of materials and finishes. Supervisory and administrative interventions include reference to H&S on various occasions throughout the project and the requiring of reporting on H&S by contractors.

Indirectly through type of procurement system used, pre-qualification of contractors on H&S, optimum project schedule, implementation of a partnering process and the facilitating of pre-planning of H&S.

RECOMMENDATIONS

The holistic influence of design on H&S should be included in the tertiary education curricula and the continuing professional development (CPD) of designers.

H&S should be considered throughout all stages of a project and should be afforded status equal to that afforded to cost, quality and schedule.

Designers should endeavour to establish clients' requirements at design brief stage.

Procurement systems should facilitate adequate provision for H&S at tender or bidding stage.

Legislation and conditions of contract should require multi-stakeholder contributions to H&S.

The duration of projects should be compatible with H&S requirements.

Design should be complete upon commencement of construction.

Extensive research should be conducted to investigate the real influence of design on H&S.

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HAZARDOUS CHEMICAL SUBSTANCES: THE ROLE OF THE DESIGNER

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ABSTRACT

The process of construction requires the use of a diverse range of materials; inter alia, chemical substances, some of which are hazardous. They are found in: adhesives, cleaning agents for brickwork and stonework, decorative and protective treatments for timber and metals, floor treatments, fungicides, cements and grouts, insulants, sealants, paints and solvents.

The hazardous nature of certain chemical substances is compounded by the nature of the construction process, inter alia: separation of design and construction; exposure to the elements; once-off-product; multi-stakeholder contributions to both design and construction; nomadic, and a low skilled workforce.

Various systems, strategies, processes, practices and interventions by designers, contractors and other stakeholders can minimize the risks. These include partnering, constructability management, total quality management [TQM], quality management system [QMS], safe work procedures [SWPs] and pre-planning.

However, design precedes construction and consequently designers have the greatest potential in terms of contributing to the minimizing and/or eliminating of the risk posed by HCSs.

Given the aforementioned, two surveys were conducted among contractors. The first was to determine the status quo with respect to HCSs. The second was to determine the role of pre-planning in health and safety, and consequently HCSs. Findings include, inter alia: HCSs are encountered; material safety data sheets (MSDSs) are not readily supplied; HCSs are stored in an arbitrary manner; various designer generated sources of health and safety information are used to varying degrees by contractors at pre-tender stage, before taking possession of site and pre-activity stage, and architects rarely or never contribute to pre-planning.

The findings amplify the need for the promulgation of UK Construction (Design and Management) type regulations in South Africa to engender optimum designer contributions.
Keywords: hazardous chemical substances (HCSs), construction, designers, pre-planning

LITERATURE SURVEY

Introduction

The use of chemicals in the construction industry is increasing, which include inter alia, paints, adhesives, flooring sealings and wood preservatives. Construction workers often underestimate the dangers of hazardous materials in the workplace, because many of the same materials are used at home [Rühl and Kluger, 1995].

Except for cigarettes, construction workers do not ordinarily, or deliberately consume hazardous chemicals on the job, however, they unwittingly consume toxic substances like lead, arsenic or pesticides [Rekus, 1994].

The Occupational Health and Safety Act [OH&SA] and its Regulations [Republic of South Africa, 1993], stipulate the minimum requirements to identify, prevent and manage risks to workers that have the potential to cause injury or disease. South African legislation has taken guidance from the United Kingdom [UK] legislation, namely the Control of Substances Hazardous to Health Regulations 1994 [COSHH] and more recently the draft Construction Regulations. The latter has a wide base of reference, inter alia, the United States, UK, European Union and New Zealand [personal discussion: Department of Labour, Inspector Tibor Szana].

Influence and role of the client

The Business Roundtable [BRT] [1995] state that the degree to which owners should involve themselves in this process should be based on the costs, benefits and risks involved. Furthermore, all owners have a legal and moral responsibility to use reasonable care to warn contractors of any non-apparent hazards present on the site, which could affect the safe performance of the construction, and to use reasonable care to prevent contractors from injuring others on site [BRT, 1995; Hinze, 1998].

The role of designers

Levitt and Samelson [1993] state that one of the recent developments in industry is the growth of programmes that foster cooperation, which hold considerable potential for improving safety in construction. Partnering brings together the various contracting groups involved in a construction project namely the client, general contractor [GC], subcontractors [SCs], the architect, engineers, and the suppliers to develop mutually acceptable goals for running a construction project.

Churcher and Alwani-Starr [1996] divide construction accidents into three classes: those due to a design decision, those due to lack of planning and those due to failure during the construction process. Many situations are avoidable if due thought is given at the early stages of projects as to how design will influence the construction process and the health and safety of workers on site.

The many difficulties experienced in the construction industry are compounded by the fact that the workplace is temporary and continuously changing, owing to the short-term nature of construction projects. In addition changing climate and tight schedule result in increased pressures on the workforce [The National Authority for Occupational Safety and Health [HAS], 1995].

Hinze and Gambatese [1994] state that designers typically distance themselves from the responsibility for safety during the construction phase, which is reflected in design codes and standards. They further state that no reference standards exist to show how design decisions could or should be made for the benefit of improved construction worker safety. In this study, design for safety suggestions were collected from the Construction Industry Institute, 11 [5.9%] out of 122 suggestions were in relation to chemical or hazardous substance exposure, listed under construction site hazards. Findings of a study conducted by Hinze and Wiegand were cited, where the authors make the recommendation that a way to make designers more responsive to worker needs is through education, an example of this was to use various design approaches that had successfully addressed worker safety on previous projects.

Hinze [1998] states that designers often dictate the "methods, means, techniques, sequences and procedures" that must be employed in constructing facility components. This occurs through the very nature of the design decisions that are made.

Curwell and March, 1986 state that the designers problem is to select materials which offer the least hazard to health but are technically and aesthetically satisfactory, and remain within cost limitations. There is a need to improve educational courses at all levels in the construction industry which includes guidance on health hazards. Concern shown over deleterious materials at the workplace has developed along with an increasing awareness of problems over pollution in the environment, from irresponsible disposal of waste products, to a point where serious public concern is now evident, especially where passive low level exposure to deleterious materials over long periods in the normal living and working environments is suspected.

The selection of building materials

In a study conducted by Mattila and Kivi [1991], 41 occupations in the construction industry were assessed with respect to, inter alia, the exposure to chemical hazards. 60.97% occupations were shown to have some risk and some health effects. 26.82% were high risk and have a definite effect on health; examples of these include cement workers, bricklayer, fitters, welders, and painters. This study effectively indicated that job hazard information systematically promotes research on the interactions between work and health, promotes the follow-up of safety and limits risks through safety training, improved procurement, and better-designed construction projects.

According to Curwell and March [1986], the following aspects should be considered when considering building products: Are the products known or suspected materials; where are the materials to be applied; what alternatives are available; what are the comparative health hazards of all the alternatives; will the technical performance and appearance of the alternatives be adequate; what are the comparative costs, and what action should be taken when a deleterious material is discovered in an existing building?

Classification of chemicals

Herrick [1998] states that the health hazards that construction workers encounter are not unique to construction. However, relative to manufacturing, construction workers conduct their work in uncontrolled settings, which may result in dramatically higher exposures than would be found in a production setting.

Routes of entry and health effects

Contaminants are classified largely on the basis of their physical and chemical characteristics, as these are important determinants of the route of exposure, and the resulting toxicity. Workers may be exposed to contaminants by inhalation, by absorption through the skin, by ingestion or by injection [such as accidental puncture wounds]. Inhalation and skin absorption are the primary routes of exposure to most materials, however, where workers are allowed to consume food in a work area, and where general hygiene is poor, ingestion may be an important source of exposure [Herrick, 1998]. The European Construction Industry [Gibb et al., 1999] provides a guide to the problems caused by materials hazardous to health, which includes health risk management and typical activities. This would be of use to designers with respect to the selection of products and their application.

Health hazards include chemicals capable of producing adverse acute or chronic health effects. These include exposures to chemical mists, vapours, gases or particulates [dusts and fumes] through inhalation or absorption through the skin.

Inhalation of high levels of solvents will result in depression of the central nervous system, and present symptoms such as headaches, dizziness and confusion, together with irritation of the eyes and breathing tract. Repeated and prolonged skin contact with solvents will cause defatting of the skin and may lead to dermatitis [Berry et al., 1995].

The Centre to Protect Workers' Rights [CPWR] [1997] states that concrete causes both an irritant and allergic contact dermatitis due to its abrasive and alkaline properties. In a survey conducted amongst various construction workers by Mattison [1993], it was identified by the safety advisor that approximately 40% of the floor fixers had had some form of dermatitis. The adhesive had been the cause, which had been changed eight times over a three-year period. A complicating factor has been that each change has caused a reaction to a different individual and thereafter the numbers have slowly increased.

Separating agents used to separate shuttering from partially or totally dried concrete are often used. The basis of separating agents include inter alia: mineral oils, aromatic and halogenated hydrocarbons. The produced vapours and mists can irritate the respiratory tract, eyes and the skin [Rühl & Kluger, 1995].

Bitumen and bitumen products are used for roadside paving and construction purposes whenever sealing or water-tight components are required. Although bitumen is no longer classified as potentially carcinogenic, the main hazard are the hydrocarbon mixes which are emitted in the form of steam or aerosol during the handling of the hot product, particularly in closed locations. Contact with the skin could lead to acne-like skin diseases and dermatitis [Gibb et al., 1999].

Gases commonly found on construction sites may generally be classified as irritating, asphyxiating or toxic. Irritant gases principally affect the eyes and respiratory tract, and irritate the skin. While effects tend to be reversible, some effects are delayed. pulmonary oedema [accumulation of fluid in the lungs] is an effect that may manifest after exposure to an irritating environment. Examples of irritant gases are ammonia, commonly used for cleaning floors, doors, windows and walls; oxides of nitrogen are associated with diesel exhaust and oxy-fuel gas welding, cutting and burning, and formaldehyde, which is used in the manufacture of plywood, particle board and textiles. Repeated exposure to formaldehyde can cause allergic reaction to both the skin and respiratory tract, and is a recognised carcinogen [i.e. will cause cancer].

Silica is found in rock, sand and concrete. Inhaled into the lungs, crystaline silica can cause silicosis, a disabling lung disease; silicosis is also suspected of causing lung cancer. Asbestos causes several diseases, including: asbestosis, a disabling disease of the lungs; lung cancer, and mesothelioma, a usually fatal cancer of the chest or abdominal cavity lining. Asbestos-related cancers usually do not appear until 20 to 30 years after exposure to asbestos [CPWR, 1997]. Synthetic mineral fibres, mineral wool, used as insulation material [glass wool and ceramic fibre products] are classified as potentially carcinogenic, as are all types of fibres provided they are a certain length [< 3_{μ}m], and diameter [> 5_{μ}m], and have a ratio between length and diameter of > 3:1, as well as the extent of resistance in the human body [Gibb et al., 1999].

RESEARCH

Selective findings of two exploratory descriptive studies are reported on.

The first study

The first study: 'Occupational health in construction' entailed three surveys. The first, a postal survey of general contractor [GC] members of two national employer associations; the second, a national postal survey of non-student members of the South African Institute of Building [SAIB]; the third, structured interviews of construction workers. To facilitate the reporting of findings the GC and SAIB responses have been consolidated.

Table 1 indicates the extent to which chemicals and dusts constitute a health problem based on the daily, weekly, fortnightly, monthly or non-exposure thereto. Given the possible range of responses in terms of frequency, an importance index [II] with a maximum of four and a minimum of zero, was computed to enable the ranking of the problems.

The following are notable: with the exception of quartz/silica, all the II values relative to workers are lower than those for GCs and SAIB members; the top three rankings for GCs and SAIB members, workers, and overall are the same, and eight problems appear within the top nine ranked problems relative to GCs and SAIB members, workers and overall.

The prevalence of problems, indicated by values greater than the midpoint of two is: GCs and SAIB members [7 No.], Worker [2 No.], and overall [4 No.].

Problem	GCs and SAIB		Worker		Overall	
	II	Ranking	II	Ranking	II	Ranking
Chemicals:						
Acids/Alkalis	1.38	10	0.63	8=	1.01	10
Bitumen/Pitch/Tar	1.32	12=	0.30	13	0.81	13=
Epoxy-resins	1.37	11	0.56	11	0.97	11
Fumes:						
Metal cutting	2.51	4	1.23	7	1.87	6
Soldering/Welding	2.22	6	0.63	8=	1.43	8
Waterproofing	1.40	9	0.63	8=	1.02	9
Mineral wools	0.81	14	-	-	0.81	13=
Oils/Petrol	2.41	5	1.72	4	2.07	4
Vapours [adhesives/paints/solvents]	2.16	7	1.61	6	1.89	5
Dusts:						
Asbestos	1.53	8	0.39	12	0.96	12
Block/Brick	3.02	3	1.95	3	2.49	3
Cement	3.44	1	2.46	1	2.95	1
Concrete	3.08	2	2.28	2	2.68	2
Quartz/Silica	1.32	12=	1.71	5	1.52	7

Table 1: Extent to which chemicals and dust constitute a problem.

On average 80.6% of GCs and SAIB members responded that they encountered health hazards on site of which 98.8% tried to reduce the hazards.

The adapting/changing of tools and equipment, changing of work practices, provision of personal protective equipment [PPE] and training was readily resorted to by both GCs and SAIB members. However, on average 10.5% substituted hazardous materials. It is notable that the priority of actions taken to reduce health hazards encountered on site is the reverse of that recommended in literature, substitution of hazardous materials being the last resort. This is likely to be an indicator that designers specify materials and finishes, and consequently prescribe the work processes.

On average GCs and SAIB members cited the incidence of ailments among workers to be: Chest illness [58.3%]; eye problems [57.3%], and skin problems e.g. dermatitis [46.7%].

The second study

The second study: ‘Pre-planning of health and safety’ entailed the survey of construction managers [CMs] in the employ of selected GC members of a regional employer association.

Pre-tender/bid site visit relative to pre-tender/bid [66.7%] predominated among sources/opportunities referred to/used for health and safety information on various occasions, followed by drawings relative to before possession of site [55.6%]; specifications relative to pre-tender/bid [50%], and drawings relative to pre-activity [50%].

Source/Opportunity	Occasion [%]		
	Pre-tender/bid	Before possession of site	Pre-activity
Pre-tender/bid site visit	66.7	38.9	27.8
Model [3-D]	16.7	27.8	5.6
Drawings	44.4	55.6	50.0
Specifications	50.0	44.4	44.4
Schedules	38.9	33.3	38.9

Table 2: Sources/Opportunities referred to/used for health and safety information on various occasions.

CMs were asked to what extent health and safety influenced the planning of various aspects, which included: site accommodation, ablutions, first aid, mess facilities, storage, access ways, materials and handling, personnel movement, plant and equipment, temporary services, and structures and waste/rubbish removal. Given the possible range of responses, namely always, sometimes, rarely and never, an II with a maximum of three and a minimum of zero was computed to enable ranking of aspects. Materials handling achieved a ranking of fourth as a result of an II of 2.78.

Engineers, clients and architects ranked fifth, sixth and seventh out of a total of eight stakeholders, in terms of the frequency of contribution to the pre-planning of health and safety: often; sometimes; rarely, and never. Given that the IIs of 1.11, 1.00 and 0.78 respectively, are below the midpoint of 1.50, their contributions cannot be regarded as prevalent. It is noteworthy that workers ranked first, health and safety consultants second, sub-contractors third, and unions fourth.

55.6% of CMs responded that the pre-planning of the health and safety reduces illness/disease. 44.4% responded in the negative.

CONCLUSIONS AND RECOMMENDATIONS

In 1994 Rekus stated: ‘Since virtually nothing is being done to protect the health of construction workers, doing *anything* would be an improvement’. This statement is still relevant. It is unfortunate that litigation and possibly further legislation is required before change takes place. Litigation is becoming commonplace at international level, therefore a preventative approach/design for safety is recommended.

This paper shows that many of the problems faced during the construction process can be improved at the design phase by the careful selection of safe or low risk building materials. It further indicates that workers do suffer from the effects of exposure to the hazardous chemicals contained in building materials. It is clear from literature that further research is needed on the effects of HCSs on the construction worker.

The construction community needs to educate designers about the ways that design decisions directly impact the construction process and thereby influence construction safety [Hinze, 1998]. Tertiary institutions, post-graduate courses, and developmental training need to include HCSs in their curricula. Further, industry associations and federations should raise the level of awareness and provide guidelines for HCSs.

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BY ACCIDENT OR DESIGN?
CAUSAL FACTORS IN CONSTRUCTION INDUSTRY ACCIDENTS

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ABSTRACT

A three-year multi-disciplinary HSE funded research project has recently commenced, with the main element of work entailing detailed studies of one hundred construction accidents. In order to develop the study methodology, a series of focus groups are being undertaken with a range of employees in the construction industry. This will reveal the perspective or viewpoint from each group within which discussion takes place; data likely to be unavailable through other published resources. Preliminary analysis of focus groups already undertaken indicates that, where participants discussed design, the role of the 'design team' was very much viewed from the concept of practical application of design, rather than a formal appraisal of the merits (or otherwise) of the technical design aspects. The results indicate that although there are failures in the technical features of design, these problems are inherently related to planning and organisational issues. To see design as an entirely technical matter is misleading and a more comprehensive and flexible approach seems desirable.

Keywords: Focus groups, design, planning, communication

INTRODUCTION

It is encouraging that annually published health and safety statistics (HSC, 1999) show a steady decrease in fatality and injury rates since 1996/7. However, the decrease in injury rates may in fact mirror a substantial increase in numbers employed in the construction sector, affecting the statistics. In reality the actual number of major injuries continues to increase, along with the considerable costs that these incur to individuals, employers and society as a whole (HSE, 1999a).

There appears to be acknowledgement of the problem within the industry yet even recently published research concerning accident causation continues to concentrate upon site-based issues such as unsafe conditions or accident inducing worker actions (e.g. Abdelhamid et al, 2000). Whilst the contribution of these factors is undisputed, previous and ongoing research (Whittington et al, 1992, Suraji et al, 2000, submitted for publication to the ASCE Journal of Construction Engineering & Management) indicates a much wider range of interactive and causal factors - especially those with their origin much earlier in the project lifecycle. These include aspects relating to the project concept and design, and general client responsibilities, which may contribute towards accident causation later in the construction process.

Project overview

A three-year multi-disciplinary HSE funded research project has recently commenced, with the main element of the work entailing detailed studies of one hundred construction accidents. These will be undertaken as soon as possible after each accident occurs, and will address the life-cycle factors identified in the Whittington and Suraji research.

The intention is to document the range of contributory design, managerial, site and individual factors implicated in accidents. It is anticipated that the results might also contribute towards development of an industry standard for accident investigation or recording and provide guidance on the better use of accident data.

In order to develop the methodology for the accident studies, initial preparatory work is in progress, and includes a detailed appraisal of existing research and database resources. There is a strong foundation of industrial co-operation and commitment to the project. Importantly, we are drawing upon knowledge and experiences from industrial practitioners to develop the accident study methods, a series of focus groups forming part of this.

FOCUS GROUPS

A focus group is a 'moderator' led discussion. Topics for discussion are gradually introduced to a group of participants and though the moderator may guide and prompt the discussions, their role is predominately passive. This enables participants to explore and consider the issues among themselves, with the ensuing discussions forming the data for analysis.

Aims

The aim of the focus groups was to gain a perspective or viewpoint from the group involved in the discussion; data likely to be unavailable through other published resources. The information provides an insight into current feelings within industry, and allows critical appraisal of previous research. This data will enable us to develop our study strategy and investigation protocol.

Selection of participants

Seven focus groups are scheduled, with five to eight representatives of employees from a hierarchical stratum in the construction process. The groups selected are client team, senior managers, site managers, operators (from large and small sites) and safety personnel. A mixed discipline group is also included.

Development of the discussion resources

A standard classification of factors involved in safety was selected, to form three categories for discussion – 'organisation and management issues, task factors and individual factors' (HSE, 1999b). These can be applied in any work situation yet, to attribute due emphasis to construction project concept and planning, an additional factor – 'project, concept, design and procurement' was also added. Under each of these headings, example topics were drawn from previous research findings, and presented as bullet-point items. An example is given below:

"Project concept, design and procurement – what are your feelings or experiences or thoughts on how safety can fail in the early stages of a project? The following prompts might guide you, but mention other things as appropriate"

On Flipchart:

- Client background (their skills and experience)
- Selection of design team
- Procurement of contractors (eg: price or safety history)
- Safety considerations (risk assessment, safety management)
- Allocation of resources (financial, skills of involved party's etc..)
- Legislation (enhances or hinders)
- Strategic design considerations

A similar style was developed for the other three discussion categories and for these, the design specific prompts related to:- managing design changes of work in progress, issues relating to site layout and design, planning and interacting with the immediate task area and use of equipment and tooling.

Questionnaire

To supplement the discussions, a short anonymous questionnaire was developed. The style was two-fold – firstly some open questions (to allow reiteration or to permit respondents to give a private view on any of the discussion points), and secondly a five point rating scale to gauge attitudes towards the issues discussed. There were 27 factors, of which five design related aspects are reported upon in this paper.

Running the Focus Groups

Our focus groups were planned to comprise between five - eight people and to last for approximately 1 ½ hours. In order to ensure direction to the discussions, participants were asked to concentrate entirely upon safety failures from their own experience.

Progress to date

Four focus groups have currently been undertaken – the mixed group, safety professionals, senior managers, and operatives from a large site. It is expected that the remaining three will be undertaken shortly and that the results may be incorporated into discussions at the conference.

RESULTS

Preliminary analysis indicates that, where participants discussed design, the role of the 'design team' was very much viewed from the concept of practical application of design, rather than a formal appraisal of the merits (or otherwise) of technical design aspects.

Points which participants mentioned most were categorised by the researchers as being issues relating to inadequacies in design, planning and communication between disciplines. To a lesser extent, aspects relating to legislatory compliance and design innovation were also discussed.

The following are example comments compiled from the discussions. Comments are deliberately not attributed to any particular focus group.

Inadequacies in design

- Compatibility of item parts not considered - for example compatibility of item weights with available lifting gear
- Tenders are made on the basis of design drawings, but if they are later found to be wrong, it is rarely possible to change the funding / work schedule – this can lead to short-cuts and subsequent higher risk of accidents
- Design modifications of work in progress are not comprehensively considered in the context of the whole design
- Designers do not consider maintenance (an example comment relevant to this was where a participant reported that maintenance to windows on a particular tower block was only possible from outside, as the windows do not open inwards. Therefore, they had to put up a scaffold every time work was required – costing thousands. Had the windows opened inwards it would have been easy and cheap to maintain).

Inadequacies in planning

- Planners just focus on the task, not site layout issues and related aspects such as traffic management
- Roads get put in at the end, why not the beginning?
- Just in time is not considered and parts delivery and storage can exacerbate problems with layout and task area design
- Designers miss things and, as they are not site-based, site personnel have to ad lib to get around design problems.

Communication issues

- People are to nice to clients
- Quantity Surveying can ruin good things from design
- The industry practice is to blame everybody else for problems
- The tender document and pre-tender health and safety plan often have a number of meaningless statements in them. A typical statement was recalled by a participant "the hazards associated with this project are not beyond the competence of a capable contractor to control. If the contractor should find any hazardous material he should notify the client and the client will then give direction of what should be done".

The participant reported, however, that they are in fact never notified by the designer team as to what the project hazards are, as ought to happen under CDM.

Legislatory related issues

- The Planning Supervisor has insufficient authority to ensure that the designer accounts for CDM responsibilities.
- Designers did not want CDM – they are now starting to think about safety, but not health
- People do not understand the legislation and blame the HSE
- CDM regulations are a paperwork exercise and do not enhance health and safety

Design innovation

- The HSE are urging for innovation to improve design factors, but this responsibility has fallen onto the shoulders of contractors and not the client team
- Nobody is really taking a lead with innovation
- More things now get made in factories (as it has become more difficult to get skilled trade-people on site) and this can inhibit good design.

It should also be noted that there were a number of under-current comments that revealed that some participants regard designers and Quantity Surveyors as distanced from site and safety issues. This was in terms of demonstrating an understanding of their responsibilities or commitment to healthy and safety, and also in respect of being a continuous contributor to the site once it is in the build and development stage.

Questionnaire responses

Participants were asked to rate the degree to which a number of factors might contribute towards accident causation. The rating scale permitted any of five possible responses for each factor, ranging from 'not at all' to 'to a very large degree'. Some comparison can be made with these responses and the focus group data, although the strength of feeling (indicated by the number of comments) may alter as data from the outstanding focus groups is incorporated.

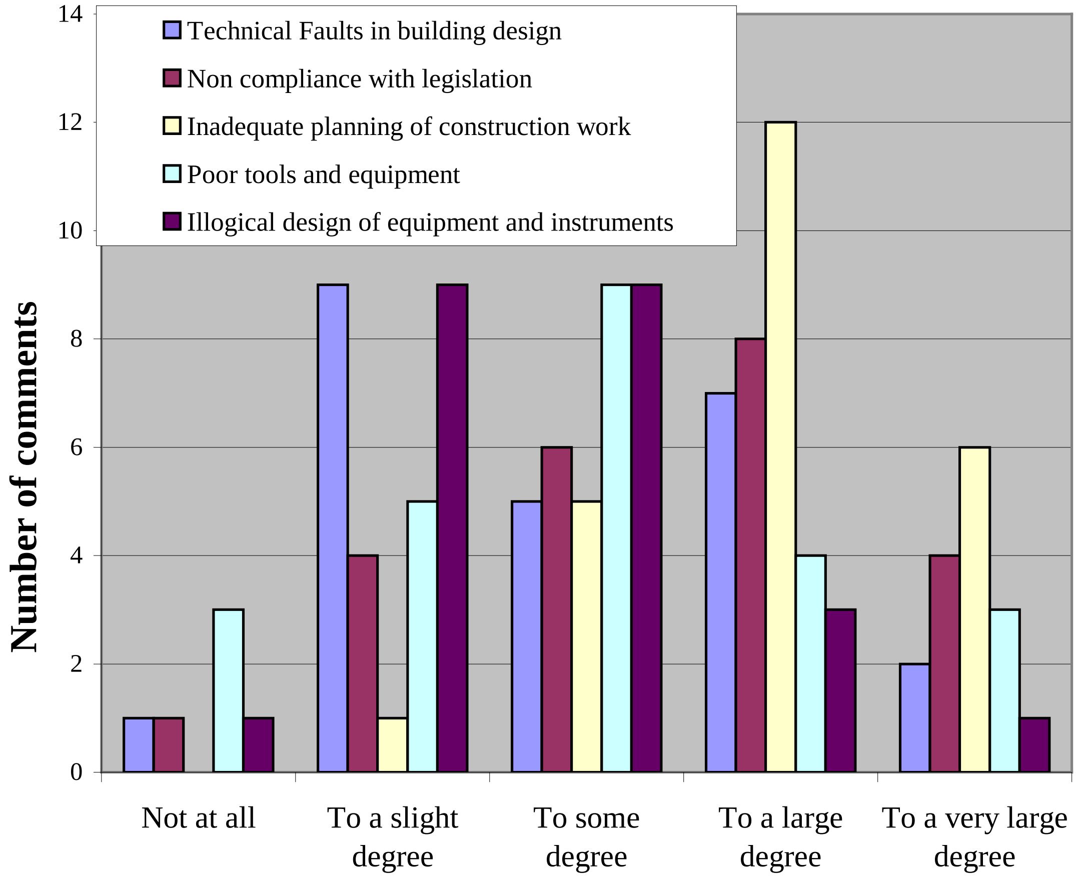

Figure 1: Participant's opinion of the degree of contribution of design factors in accident causation

CONCLUDING REMARKS

The data analysis that has been undertaken so far indicates that, although there are failures in the technical features of design, these problems are inherently related to planning and organisational issues. To see design as an entirely technical issue is misleading and a more comprehensive and flexible approach seems desirable.

The need for improvement in communication between different disciplines has been highlighted. Likewise the development of the public profile and accessibility of designers to site staff also appears overdue. An undercurrent blame culture (attributed here to designers, but overall aimed towards a range of different disciplines) was detected. At the very least this indicates a need to enhance the understanding of professional skills and responsibilities among those employed in the industry.

POST SCRIPT

It is expected that the remainder of the focus groups will be completed shortly. This should allow more detailed data analysis and is likely to offer a greater indication of strength or weaknesses in the comments made.

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CONSTRAINT-RESPONSE THEORY OF CONSTRUCTION ACCIDENT CAUSATION

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ABSTRACT

Designing for safety to prevent accidents during construction, requires a comprehensive understanding of why accidents happen and their causation processes. This paper proposes a theory of accident causation for the construction industry, representing the underlying and complex interaction of factors in the causation process. The theory describes multiple paths of constraints and responses experienced by all parties involved, from project conception, through design and construction, which may generate situations or conditions to lead to increasing risks of accident. It maps causal factors of accidents: distal factors and proximal factors, which may be generated by clients, client's team, designers, contractors and subcontractors as well as operatives. These factors are taken into account as contributory factors to lead to disturbances of plant or equipment, structures or temporary structures, operatives, materials, services, ground and other facilities. Distal factors classified as project conception constraints, client responses, project design constraints, designer responses, project management constraints, project management responses, construction management constraints, construction management responses, sub-contractor constraints, sub-contractor response, and operative constraints are presented. Proximal factors classified as inappropriate construction planning, inappropriate construction control, inappropriate construction operation, inappropriate site condition, and inappropriate operative action are also described and validated by studying records of accident investigation provided by UK Health & Safety Executive.

Keywords: Accident causation, construction, constraint-response theory, distal factors, proximal factors.

INTRODUCTION

Most older theories of industrial accident, reviewed by Hale & Hale (1972) and Brown (1990), address only operative behaviour. More recent theories of construction accident causation (e.g. Whittington, 1992) include management and organisational factors having influence over the site situation. However, there has been no structured approach to management or organisational behaviour in accident causation. Current theories address how and why operatives have accidents, but not how and why managerial or professional participants stimulate unsafe operative actions or site conditions. Accident investigations tend to deal only with how operatives have an accident and stop when unsafe site behaviour or conditions are discovered.

A model is required to explain how and why any participant involved in a construction project can contribute to an accident. Using such a model, investigation of all the contributory factors could be carried out and the project roles with control over those factors identified. This would lead to more effective accident prevention strategies. Such a strategic approach should take account of construction management, project management and design, as well as client and environmental factors related to project conception.

This paper introduces a theory of construction accident causation that models the complex interaction of all project participants. The concepts are based on literature review and experience. First, basic principles of the **constraint-response** theory are described. Second, models representing the structure of causal factors are presented. These factors are broadly classified as distal factors and proximal factors, to distinguish between factors which contribute directly to an accident and factors, outside the construction process, but applying constraints to project participants and hence, indirectly, increasing the risk of accidents. Finally, results of validation of proximal factors are summarised. The paper focuses throughout on the contribution that the design process makes to the generation of accident risk, although the principles can be applied to the contributions of all participants. This theory is represented by a model which should allow more rigorous and comprehensive accident investigation and analysis of causation. In this way, feedback to designers of the consequences of their decisions will be more informative. Throughout the paper, the term ‘designer’ refers to designers of constructed facilities or buildings (architects, engineers).

CONSTRAINT-RESPONSE THEORY

Principles of the theory

This theory embraces management, organisational and operational features of the construction process modelled to assist mapping of accident causation. The features incorporate project conception, management, design, and construction. The model incorporates many factors of deficiency, associated with situations, conditions and operational systems in the construction process, their precursors in early project activity and its environment, and their consequences. These deficiencies are classified as: **inappropriate construction planning**, **inappropriate construction control**, **inappropriate construction operation**, and **inappropriate site condition**. The model also includes **inappropriate operative action** that leads directly to accident occurrence. These deficiencies, in that they lead directly to increased risk of accident, are classified as proximal factors. The use of inappropriate to describe deficiencies takes account of many factors that are not, in themselves, unsafe but in some circumstances could raise the risk of accident.

Distal factors are those that can lead, with inappropriate responses from one or more project participants, indirectly, to increasing risks of accident causation, by the introduction of proximal factors. Distal factors are managerial or organisational constraints experienced by participants, and their responses. This approach assists in the analysis of the influences on, and contributions of, designers in the creation of a safe construction activity.

The fundamental concepts of the theory, as they relate to designers, are as follows:

1. A designer may introduce factors leading directly or indirectly to accidents. This embraces the theory of human error, that almost all factors leading to accidents

arise, at least in part, from human action or inaction to eliminate, reduce or avoid accident risk.

2. Designers work within constraints arising from the situation of the designer's own organisation, another project participant or the project environment. For example, client's decisions at project conception can introduce resource or time constraints for the designer; or a contractor can, by changing the construction sequence, produce constraints to the provision of design information.
3. A designer's response to such constraints will influence construction activity; for example, possibly, providing incomplete information, leading to an inappropriate construction process and increased risk of accident.
4. An inappropriate construction process would include inappropriate construction planning, control, operation, and site condition, recognising the idea of a latent failure (Reason, 1990); and inappropriate operative action, often providing, in Reason's terminology, the triggering event.
5. Consistent with domino theory of accident causation, the structure of the model creates a multiple path domino sequence in which an accident may have multifactorial sources (Petersen, 1971).

Structure of the model

Following the fundamental concepts described above, the causal process is structured into three general parts: distal factors, proximal factors, and the accident. The analysis of the accident events determines how accidents happen, whereas analysis of distal and proximal causes provided the answers to the question why.

The further development of the relationships 'upstream' of the site (Figure 1) provides structure to investigation and analysis of distal factors, by modelling the way that designers and others, by their responses to constraints, may provide constraints to the other members of the project team. Though most designer's responses may not lead directly to accidents, responses such as increasing design complexity, staffing part of design process with contract staff, reducing design resources, or cutting cost of components may result in constraints in other areas of the project. Some responses, such as late design changes, may also provide 'upstream' constraints for the client and force reconsideration of, for example, project scope.

Taxonomy of Accidents

In this paper, the term 'undesired event' is used rather than accident to avoid the frequent assumption that an accident must involve injury. Undesired events are defined as operational disturbances, or failure mechanisms, and their consequences. The consequences could be injury or damage to people, to property or the environment, or 'near misses'. The sequence of operational disturbance can be differentiated as undesired event and ultimate undesired event. For example, a temporary support structure collapse, causing heavy equipment to overturn and trapping an operative, happened because one of the foundation supports failed. The failure of the foundation is the undesired event. The collapse, overturn, and fall are the ultimate undesired event and the consequences are damage to the equipment and injury to the operative. The severity of the event is classified as destruction, major damage, or minor damage to property or environment; or fatal, major or minor injury. This will permit future analysis of the importance of causal factors by correlating them with the severity of the outcome.

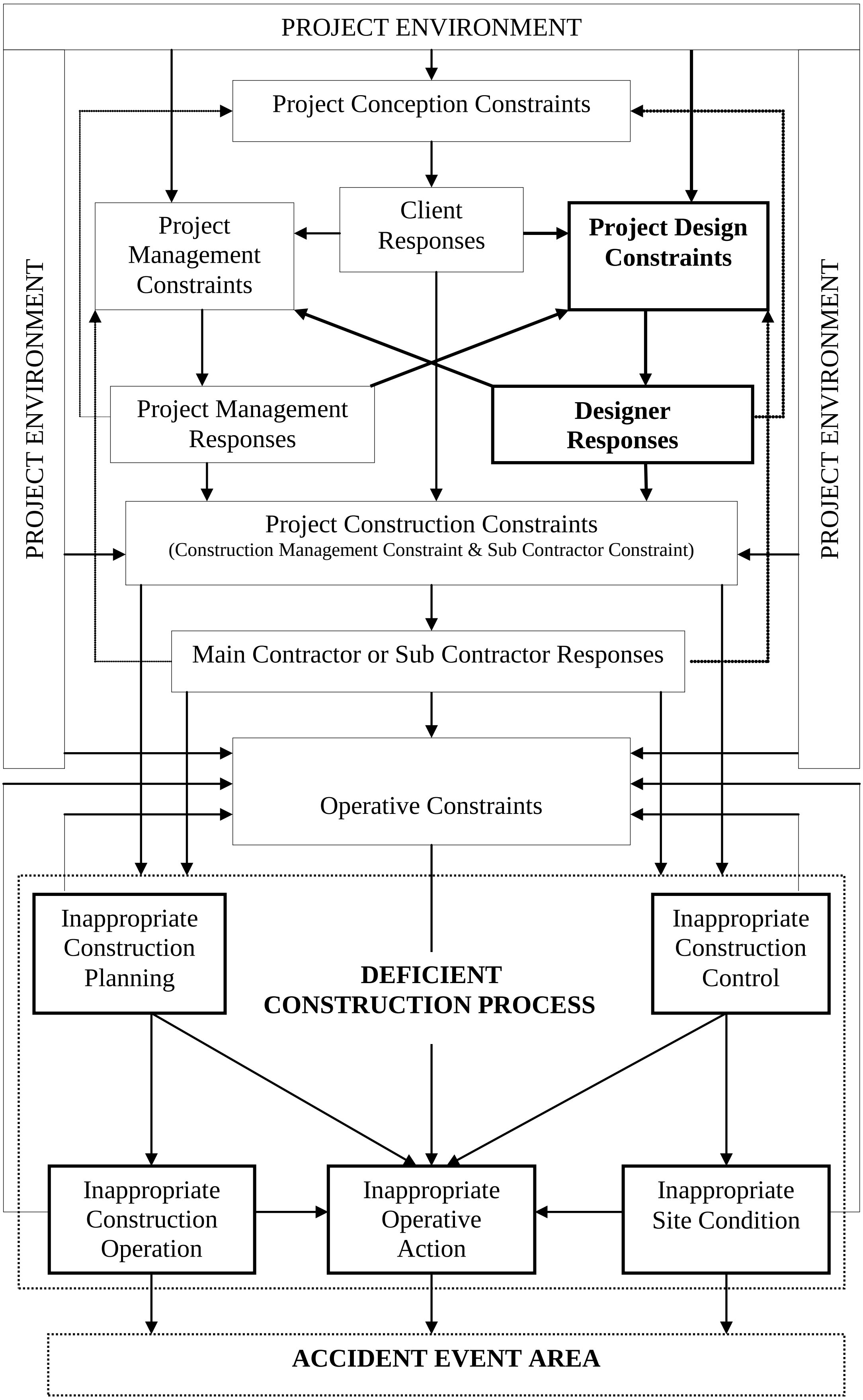

Figure 1. Constraint Response Theory of Construction Accident Causation

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CAUSAL FACTOR CLASSIFICATION

Proximal factors

This classification is intended to assist investigation of the root causes and to determine which project roles could reduce, eliminate or avoid their occurrence. These classes of deficient construction process are defined as follows:

1. **Inappropriate Construction Planning (***ICP***):** inadequate analysis or formulation of the construction plan, method statement or schedule, in relation to the risk of undesired events which may lead to injury or damage to construction personnel, the general public, the property of either or the environment; e.g. inadequate method statement and inadequate structural design for temporary support structures.
2. **Inappropriate Construction Control (***ICC***):** inadequate, either in quantity or quality, effort to direct or supervise the factors of construction such as to cause deviation of the construction operations from plan, and increase the risk of undesired events; e.g. inadequate control of plant or equipment operation or inadequate supervision of operative work.
3. **Inappropriate site condition (*ISC*):** unsuitable physical environment, in which a construction operation takes place, which may impinge on the performance of the operation and directly increase the risk of undesired events; e.g. unsuitable existing topography or unsuitable weather for the operation being undertaken.
4. **Inappropriate construction operation (*ICO*)**: unsuitable process of production of permanent or temporary works that increases the risk of undesired events; e.g. improper construction procedure or improper plant or equipment operation.
5. **Inappropriate operative action (***IOA***):** improper action or inaction, either intentionally or unintentionally, by an operative which may result in increasing the risk of undesired events; e.g. carelessness or failure to adopt standard procedures.

Distal factors

Distal factors are defined as follows:

1. **Project Conception Constraints** (*PPC*): constraints arising from the internal or external project environment that confront clients during the project conception phase; e.g. difficulties in obtaining funding or environmental legislation.
2. **Client Responses** (*CR*): action (or inaction) by the client in response to constraints during development of a project brief; e.g. reduce project budget or add new project criteria.
3. **Project Design Constraint** (*PDC*): limitations or problems confronting designers during the design process. These may be stimulated by client's responses, project management responses or the business environment of the design organisation; e.g. modified technical requirement or accelerated design programme.
4. **Designer Response** (*DR*): action or inaction by designers to confront the constraints existing during project design stage; e.g. increase design complexity or sub-let part of design process.
5. **Project Management Constraint** (*PMC*): difficulties arising from the internal or external organisation which confront the client or client's professional team during project planning & design or construction phases; e.g. late delivery of design detail or limited availability of suitable contractors.

6. **Project Management Response** (*PMR*): action or inaction by the client or client's professional team to confront an existing constraint during the project implementation stage. These are for example: increase time pressure on design team or inadequate contractor pre-qualification.
7. **Construction management constraint** (*CMC*): is defined as difficulties arising from client, project management and designer responses, or the project environment, which confront contractors during the project construction stage; e.g. short programme time scale and design variations.
8. **Construction management response** (*CMR*): action or inaction by construction managers to confront construction management constraints or problems created by the project environment; e.g. adjust level of supervision or fail to supply safety equipment.
9. **Subcontractor Constraint** (*SSC*): similar constraints to those that confront main contractors; e.g. cash flow problems or pressure from other contracts for resources.
10. **Subcontractor response** (*SCR*): action or inaction by the subcontractors to confront the constraints; e.g. slow down work or reallocate resources to another site.
11. **Operative constraint** (*OC*): any factor, from whatever source, which may distract operatives in carrying out construction activity; e.g. social or domestic pressure or physical disability.

VALIDATION OF THE THEORY

Validation method

Analysis of accident data provided by UK Health & Safety Executive (HSE) was conducted to validate the causal factors previously described. Data from inspectors' investigation reports generally only covers the proximal factors. Therefore, further validation by direct accident case studies is being undertaken (Ref to Loughborough/UMIST paper). The proximal factor analysis involved systematic recording of every fact present, in the investigation reports, by textual analysis. Only those proximal factors specifically alluded to in the report were recorded and the use of inferential logic avoided.

Preliminary Findings

Study of around 500 construction accident records was undertaken, during which evidence was found of 68 out of the 70 hypothetical proximal factors. Analysis at the level of type of proximal factor is shown in Table 1. Percentages total more than 100 as 65% of accidents have multiple proximal factors.

Table 1 Types of Proximal Factors Involved in the Accident Causation

Proximal Factor	**% of Accidents caused by the proximal factors**
1. Inappropriate Construction Planning	33.40%
2. Inappropriate Construction Control	14.29%
3. Inappropriate Construction Operation	72.48%
4. Inappropriate Site Condition	7.98%
5. Inappropriate Operative Action	34.66%

Analysing each of these types of proximal factor has identified the major contributors to accident causation, as shown in Table 2. Asterisked factors are those for which consideration at the design stage could contribute to reduction in accident risks.

Table 2 Major Contributors to Accident Causation

Type of Factor	**Major proximal factors (Involved in more than 2.5 % of all accidents)**	**Percent**
Inappropriate Construction Planning	Inadequate method statement *	10.71%
	Inadequate preparatory training	9.87%
	Inadequate identification and assessment of risk*	9.24%
	Inadequate planning of construction work*	5.46%
	Inadequate safety plan*	3.57%
	Inadequate site investigation*	3.57%
	Inadequate structural design for temporary support structures	2.52%
Inappropriate Construction Control	Inadequate supervision of operative work	4.41%
	Inadequate control of plant or equipment operation	3.36%
Inappropriate Site Condition	Inappropriate ground condition*	3.57%
	Unsuitable weather or climatic conditions*	3.36%
Inappropriate Construction Operation	Breach of regulation or code of practice*	24.58%
	Improper construction procedure*	17.86%
	Inadequate safety facilities	14.92%
	Defective equipment or vehicle	9.24%
	Inadequate temporary structure*	8.40%
	Improper plant or equipment operation	7.98%
	Inadequate provision of safety warnings or other precautions	5.04%
	Untrained or inexperienced workforce*	4.20%
	Defective site services	3.99%
	Unsuitable plant or equipment	3.78%
	Improper instruction to operatives*	3.57%
	Inadequate working platform including no guard rails*	2.52%
Inappropriate Operative Action	Carelessness	10.08%
	Judgement error, underestimate, overconfidence	7.35%
	Failure to follow instructions	6.51%
	Improper or inadequate use of PPE	6.09%
	Improper working position*	4.41%
	Failure to adopt standard procedures *	3.78%

CONCLUSIONS

The constraint-response theory of construction accident causation was found to be suitable for developing a comprehensive causal model. In this theory, causal factors of accidents are conveniently categorised as proximal factors and distal factors. The proximal factors include inappropriate construction planning, inappropriate construction control, inappropriate construction operation, inappropriate site condition, and inappropriate operative action that can be identified as the immediate causes of construction accidents. The distal factors include project conception constraints, project design constraints, project management constraints, construction management constraints, sub-contractor constraints, and operative constraints precipitating potentially unsafe responses by clients, designers, client's project team, contractors, sub-contractors and operatives. These constraints and responses include the influence of management & organisational factors, environmental factors such as economic, legislative, political and social as well as individual participant factors.

The analysis of 500 accident records provided by the HSE validated 97% of the hypothetical proximal factors. From the analysis of the HSE data, the most frequent category of proximal cause is Inappropriate Construction Operation, occurring in 72 % of all construction accidents. Inappropriate Construction Planning and Inappropriate Operative Action are also frequently encountered. Inappropriate Construction Control does not feature as frequently as might be expected, when compared with the frequency of Inappropriate Operative Action. This might be explained, at least in part, by HSE inspectors focus on legal requirements rather than on uncovering all the contributory factors. A more structured and detailed investigation process would promote a clearer understanding of the relative importance of all proximal and distal factors. This is essential if the full accident causal process is to be properly understood and evaluated. Current associated research, funded by HSE and in collaboration with the Departments of Civil and Building Engineering and Human Sciences at Loughborough University is making progress towards this objective.

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INCORPORATING SITE MANAGEMENT FACTORS INTO DESIGN FOR A SAFE CONSTRUCTION PROCESS

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ABSTRACT

Past and current models of accident causation propose organisation and management as major contributory factors to construction accidents. However, no attempts have yet been made to further analyse these as relevant inputs to designing for safety. This paper considers the potential for incorporating site management factors into design activities for a safe construction process. First, issues on designing for construction safety are introduced. Second, the paper identifies site management factors in the construction process. The site management factors are classified as construction planning factors, construction control factors, and construction operation factors. Then, the paper proposes ways in which designers may contribute to improvement in site management in delivering a safe construction process.

Keywords: construction safety, design, site management.

INTRODUCTION

Who is responsible for designing for construction safety: architects, engineers, contractors, or perhaps even clients? The answer will depend on how we define design, construction and, even more importantly, responsibility. Design of the constructed facility is normally the responsibility of the architect and engineer, whereas design of the construction process is conventionally considered to be the contractor's responsibility. In each case it is the clear duty of those responsible to carry out these responsibilities with concern for the safety of those involved in the construction process. It is now generally understood in Europe, enshrined in European legislation and, more specifically, since the introduction in 1994 of the Construction [Design and Management] (CDM) Regulations into UK legislation, that design of the constructed facility should take into account foreseeable risks during the construction process. Risks related to the technology of the constructed facility or the construction process are clearly within the scope of this requirement, but what about risks associated with the organisation and management of the construction process? Can, and should, the designer contribute to their mitigation or avoidance?

It has long been accepted that accident causation is almost always multi-factorial, described variously as a sequence similar to domino collapse (Heinrich, 1969), or latent factors creating a high risk situation with a triggering event precipitating the accident (Reason, 1990; Groeneweg, 1994). These models of causation recognise, specifically, the influence of actions upstream of the construction site but do not suggest that such an action has directly caused the accident, except in the most extreme situations such as failure of a structural component because of its inability to withstand stresses arising during the erection process. Usually, precautions taken during construction can mitigate or avoid risks created by actions upstream. It is, however, becoming increasingly accepted that this possibility of risk reduction in the planning or control of the construction process is analogous to fire-fighting and does not absolve designers of responsibility for trying to anticipate these risks and design them out before construction starts.

Designers, generally, rarely realise the extent to which their designs or actions during the design process may influence safety. In industrial accidents, design has been found to contribute to 33% of incidents (Reason, 1990). Groeneweg (1994) includes design aspects as one of his general failure types, or latent failures, in accident causation. Maitra (1999) quotes a report of construction accident analyses across Europe suggesting that 60% of construction accidents could have been eliminated, reduced, or avoided with more thought at the design stage by designers.

The domino type of causation model has recently been extended by the authors to demonstrate the specific contributions of all the participants in a construction project (Suraji and Duff, 2000; Suraji, Duff & Peckitt, 2000). This **Constraint-Response** model suggests that all participants operate within constraints imposed by other participants or by the project environment; and their responses to these constraints, in turn, provide many of the constraints for other participants later in the project organisation. If the responses are inappropriate, they can create latent factors, or even directly precipitate triggering events in accident causation. Other papers by the authors, cited above, describe the model in detail and the results of its validation using records of over 500 construction accidents investigated by the UK Health & Safety Executive (HSE). In this paper the authors consider the proximate factors, or direct causes, in construction accident causation that were uncovered in this validation process and the current or potential impact of designers on these factors. The question to be addressed is “Can designers, through their design work or by involvement in the construction process, reduce accident risk by applying their design skills, and their accumulated knowledge of the construction project and its environment, to inform management of the construction process?”

Until relatively recently construction matters were considered to be beyond the scope of design responsibility. More recently, this old paradigm has altered. Constructability research has brought the concept of integrating construction knowledge into design (e.g. Tatum, 1987a, 1987b, 1990). In Europe, implementation of the Temporary & Mobile Construction Sites Directive (Appendix 4), e.g. CDM Regulations, requires designers to include construction risk assessment in the design process. Designers should design to eliminate, reduce or avoid the risk of accident during construction. They must include construction methods as one of their design considerations and provide clear notification to contractors of identifiable residual risk.

This paper expands the concept of designing for construction safety by incorporating consideration of site management factors into design activity. First, the paper discusses site management factors in construction accident causation. The influence of design on these factors is then considered. Finally, the paper addresses the issue of whether designers could contribute to the site management process in order to assist in accident risk reduction.

SITE MANAGEMENT FACTORS

A site management factor is defined as one concerned with the technology or operational methods, including plant, equipment, temporary support structures and the like, or the management and organisational aspects of the construction process. The management or organisational aspects include planning, control and communication procedures, used to govern the construction operation.

The following paragraphs detail the classification and description of site management factors, derived from literature review and experience. They do not include factors in the project environment. The site management factors are classified as construction planning factors, construction control factors, and construction operation factors.

- **Construction Planning Factors (***CPF***)** are components of the planning and design of construction operations including technical design, and organisational and logistical planning of constructions works and design for temporary works. The full list of these factors is shown in Table 1.

Table 1 Construction Planning Factors

Code	**Construction Planning Factors**
CPF-01	Design of access structures
CPF-02	Development of method statements
CPF-03	Identification and assessment of risks
CPF-04	Planning & design of plant or equipment operations
CPF-05	Planning & design of site services
CPF-06	Planning of construction works
CPF-07	Preparatory training
CPF-08	Safety plans
CPF-09	Site investigations
CPF-10	Site layout plans
CPF-11	Structural design for M & E installation works
CPF-12	Structural design for temporary support structures
CPF-13	Other

- **Construction Control Factors (***CCF***)** are components of the control of construction operations, such as control of plant or equipment operation, supervision of operatives work, and control of reliability or appropriateness of temporary works used in the construction operation. The full list of these factors is shown in Table 2.

Table 2 Construction Control Factors

Code	Construction Control Factors
CCF-01	Control of dangerous chemicals or substances
CCF-02	Control of ground conditions
CCF-03	Control of material or component storage & handling
CCF-04	Control of plant or equipment operations
CCF-05	Control of safety facilities and protective equipment
CCF-06	Control of systems of works
CCF-07	Control of the stability of temporary structures
CCF-08	Control of worksite condition (housekeeping)
CCF-09	Control or protection of weather effects
CCF-10	Supervision of operative work
CCF-11	Other

- **Construction Operation Factors** (*COF*) are technical or operational components of the process of constructing facilities or buildings. In order to ensure safe operations they must include, for example, appropriate construction methods, suitable equipment or plant, adequate working space, and comfortable working positions. Table 3 shows the full list of construction operation factors.

Table 3 Construction Operation Factors

Code	Construction Operation Factors
COF-01	Access/ egress reliability & stability
COF-02	Adequacy of illumination or lighting
COF-03	Adequacy of ventilation
COF-04	Adequacy of communication or co-ordination
COF-05	Appropriateness of construction procedures
COF-06	Appropriateness of instructions to operatives
COF-07	Availability of safety facilities
COF-08	Completeness and clarity of working drawings
COF-09	Compliance with regulations or codes of practice
COF-10	Equipments or vehicles capability
COF-11	Maintenance of equipment or plant
COF-12	Maintenance of temporary structures
COF-13	Correct plant or equipment operations
COF-14	Correct and sufficient setting out
COF-15	Adequateness of site layout
COF-16	Proper stacking and routing of materials or components
COF-17	Correct and sufficient provision of PPE
COF-18	Correct and sufficient safety warnings or other precautions
COF-19	Reliability of temporary structures
COF-20	Reliability of traffic control systems.
COF-21	Site services reliability
COF-22	Stability of working platforms and provision of guard rails
COF-23	Suitability of materials or components
COF-24	Suitability of plant or equipment

COF-25	Tidiness of workplaces or poor housekeeping
COF-26	Trained or experienced workforces
COF-27	Usability of working tools or instruments
COF-28	Working space comfort and sufficiency
COF-29	Other

Inappropriate Site Management Factors

Contractors are the main contributors in establishing appropriate, i.e. safe, planning, control and operational management factors. However, they operate under a number of constraints, including the actions of designers (Suraji and Duff, 2000), and may fail to provide safe working conditions, at least in part, as a result of these constraints. Current research (Suraji, Duff & Peckitt, 2000) finds that inappropriate construction planning (33.4%), inappropriate construction control (14.3%), and inappropriate construction operation (72.5%) are among frequent contributory factors in construction accidents.

INCORPORATING SITE MANAGEMENT FACTORS INTO THE DESIGN PROCESS

Designers have contributed technically to construction accidents in various ways (Maitra, 1999). For example:

- Temporary loading case, which occurred during erection, had not been considered by the designers;
- Possible temporary instability during installing a structure was not stated clearly in a method statement;
- Possible impact of designs on construction risks were not clearly added by highlighted notes in design drawings;
- Possible requirement to shore structures during deeper trench excavations was not included in the technical specification, leading to a trench collapse.

These omissions can clearly be related to one, or more, of the factors listed in Tables 1, 2 and 3. In fact, consideration of each of the factors in Table 1, Construction Planning, shows that virtually all of them could benefit from consideration or input by designers, either during the process of design or during the planning of the construction process. In many instances those contributions would not be directly related to technical aspects of design but using familiarity with the building and its immediate environment to anticipate and avoid risks arising from inappropriate planning decisions. For example, an engineer's familiarity with the content of site investigations, having considered them in relation to the engineering design of foundations, would provide the opportunity for informed comment on any proposed excavation processes; or an architect's familiarity with spatial dimensions, having considered them in relation to design of building use and occupant circulation, would allow informed comment on the difficulty of proposed services installation or fitting out activities. The same conclusions can be reached in respect of many of the factors in Tables 2 and 3, Construction Control and Operation.

In other ways, designers, through inappropriate responses, such as late changes in designs, high design complexity, or reducing design resources, to their own constraints, may produce management constraints and avoidable problems during construction. Simply using up a disproportionate amount of the whole project duration will put the construction process under time pressure and, thus, increase the risk of accident due to carelessness or deliberate corner cutting. In other words, both the output of design process and how designers manage this process may provide unnecessary technical, operational and organisational risks for builders.

DESIGNER'S CONTRIBUTION TO A SAFE CONSTRUCTION PROCESS

Designers have a significant role in designing for construction safety. The role is not only associated with providing better design outputs but also minimising negative effects of the design process and maximising the value of their design skills and project knowledge.

There are several generic approaches available to designers that will impact on factors in the planning, control and operation of the construction process. First, the design of the building itself can facilitate normal, foreseeable construction processes. The designers can consider in the designs such factors as:

- extra loads of the structures during construction;
- facilities for handling built into elements of the structures;
- facilities for location and fixing of temporary works, such as access;
- comfortable access to inaccessible parts of the building during construction (and maintenance);
- influences of the building environment, such as ground conditions and building topography, on the construction process.

Second, information, collected for the purpose of design or during the design activity, and having potential impact on the safety (and efficiency) of the construction process, can be made available to the contractor through the design documentation. Risk assessments are now required but, in many cases, without detailed knowledge of the construction process planned, designers will not be aware of the potential value of all the information held. Ways should be sought to structure, document and transfer this knowledge in a conveniently accessible form.

Third, designers can make their accumulated knowledge and understanding of the project available to the contractor through attendance at planning meetings. This will help to avoid contractors overlooking accident risks or simply being unaware of risk factors, through less familiarity with the features of the project.

For these ideas to be feasible, there are a number of changes that need to take place. First, the mindset of many designers needs to change. Designers have to become aware that the output and organisation of the design process do not only affect the construction process in technical ways. Complicated design or high specification of materials may cause gaps with available construction technology, difficulty in obtaining materials required, unavailability of equipment or plant, or insufficient experience of builders. These deficiencies can contribute to construction accidents.

For example: significant construction accident causes are found to include inexperienced workforce (4.2%), unsuitable construction materials (1.7%) (Suraji, Duff and Peckitt, 2000).

Second, the mindset of many contractors needs to change. The planning, control and operation of the construction process is, of course, the responsibility of the contractor; but the designer has considerably more knowledge of the project than is normally made available to the contractor, in the exercise of this responsibility. This knowledge should be sought and welcomed.

Third, the designer needs help in defining the knowledge that could assist the contractor. Designers cannot be expected to anticipate the health and safety significance of all the information and understanding that they possess. A good beginning to achieving this would be more comprehensive data on accident causation, and particularly the underlying or distal causes that include the effects of design and the design process, so that designers could begin to understand the wide range of influences that they have over the management of the construction site.

Fourth, contractual and economic issues will have to be addressed. Acceptance of more responsibility and involvement of designers comes at a price. Although the huge social and economic costs of construction accidents, and not just injury related ones, seems to provide clear incentive to improve the management of construction, increased involvement of designers will be costly. The potential costs and benefits require detailed investigation.

CONCLUSIONS

Designers have a much larger potential contribution, to increasing the safety of construction operations, than most currently make, including:

- incorporating features in their designs that make construction easier and safer, not just by avoiding difficult-to-build designs, but also by adding features to positively assist construction;
- making information collected during the design process available to construction management, particularly during the planning process;
- taking a positive role in the planning process by attendance at, and contribution of accumulated project knowledge to, planning meetings.

This cannot be achieved easily. It requires changes in mind-set of designers and contractors, clearer understanding of how an effective contribution might be made, changes in the contractual arrangements and clear justification for the changes.

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THE ROLE OF INFORMATION TECHNOLOGY IN IMPROVING SAFETY AND HEALTH INPUT INTO THE DESIGN PHASE. A PLANNING SUPERVISORS VIEW.

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ABSTRACT

During the past twenty-five years there has been a rapid growth in the use of computers by designers. Now most designers have desktop or lap top personal computers with world-wide internet connections.

The Flixborough disaster in June 1974, resulted in 28 deaths as a result of a massive vapour cloud explosion, caused by the inadequate design of a temporary by-pass line.The disaster brought home to designers the need for detailed design reviews.

United Kingdom Health and Safety Legislation has been developed to implement the requirements of European Directives, in particular the European Mobile Worksites Directive (92/57/EEC). Designers have a legal duty to assess risks, to mitigate them at the design stage and provide information on residual risks to persons undertaking construction work (including new work, maintenance and demolition).

Computers are now extensively used to support Design Reviews and to document Risk Assessments and Residual Risks for inclusion in Construction Safety Plans.
They also permit the rapid access to records for plant operations, training and future construction work

After the initial capital cost of computer equipment and staff training, design work can be executed more quickly and from offices at more than one location. both in country and world-wide.

Key Words: computers, legal, reviews, internet, costs.

INTRODUCTION

1970’s computers were large, slow to operate and employed by limited number of organisations. By 2000 most Design Engineers have desktop or portable Personal Computers (PC). Input and output on screen is instantaneous and may be networked throughout offices, linked via E-mail / Internet to offices and work sites throughout the world.

LEGAL BACKGROUND

In June 1974 the chemical plant at Flixborough (United Kingdom) was ripped apart by massive explosion. There were 28 fatalities and extensive damage. The **Cause of disaster** was identified as **inadequate design** of a temporary bypass line leading to leakage of cyclohexane and ignition of a vapour cloud.

The Health and Safety at Work etc Act 1974 [1]

- Section 6, 37 and 53 of particular relevance to design work.
- Section 6 places duties on the Designers, Manufacturers, Importers and Suppliers of articles to ensure, so far as is reasonably practicable, that they are designed and constructed to be safe and without risk to health when properly used.
- Section 37 states that where offences are committed by Corporate Bodies and Directors and Managers have consented or connived at the committing of offences or are negligent in their duties, they may also be guilty of the same offence and be charged and punished if found guilty.
- Section 53 defines articles as any plant designed for use or operation by persons at work or any component in any such plant.

Following the passing of the act, directors and senior managers of design organisations realised that they had a clear duty to avoid a "Flixborough" disaster. Efforts were made to ensure that designs were subjected to a series of Design Reviews not least to keep themselves from being prosecuted, and, if found guilty, fined and possibly imprisoned. In 1992 The European Directive 92/57/EEC (The eighth individual Directive under Article 16 (1) the Framework Directive), (The Mobile Worksites Directive) (ref. 2) lead to:

The Construction (Design and Management) Regulations 1994 (CDM Regulations) [3,4]

Regulation 2 Interpretations gives clear definitions of Construction Work and Structures.

Regulation 13 Requirement of Designers (ref. 5) extended the duties expressed in Sections 6 and 37 of HSW Act. Designers now have a clear duty to identify risks, mitigate them where possible and to provide information on residual risks to those undertaking construction works (which includes maintenance and demolition).

Countries throughout Europe will have had to introduce similar legislation to the UK "CDM" Regulations, for example the Irish Republic Safety, Health and Welfare (Construction) Regulations 1995.

DESIGN REVIEWS

Although design reviews are essential for complex process plant, the CDM regulations [6] clearly require reviews for many other structures. Since 1982 the author has been responsible for reviewing design documents for the Petrochemical, Pharmaceutical, Food, Paint and Perfume, Printing Ink Manufacturers, Warehouses, Schools, Supermarkets, Sheltered Accommodation, Student Flats and Domestic Housing, and a Hospital extension. The reviews have been followed by visits to construction sites to audit the management of the construction works.

Originally reviews were all laboriously hand recorded, typed up and mailed to clients and contractors, now with the use of a variety of computer systems, much of the work is recorded and transmitted electronically.

A great advantage of computer systems is their flexibility, allowing information to be rapidly "Cut and Pasted" from one document to another and drawing from an electronic data base, inputted into a number of Safety Plan Templates to meet the requirements for the different types of construction works.

Hazard and Operability Reviews (HAZOP):

(Used mainly in the design of process plant)

A team comprising of designers, client's operations personnel, maintenance and safety personnel review the process and instrumentation drawings by applying a series of Guide Words and Deviations from Normal operation, detail the consequences and the safe guards and identify the actions to be taken to correct the deviation (for example, broken level indicator on a storage tank leading to overflow; action:-consider fitting back up indicator). A typical review over some three days (20 hours) may lead to some 50 actions by team members. A typical six-hour review took a further three to four hours to record and write up the action sheets. The use of an electronic database had the actions detailed in the review meeting and issued almost immediately. It was common with the manual system to provide both a chairman and a secretary; the electronic system could be handled by the chairman. (In fact a junior engineer often acts as the secretary to gain experience). Action sheets can be E-mailed to and from the team members and the status of the actions can be tracked. The issue of a Close Out Report is expedited once all the actions have been mutually resolved. Where Design and Construction Projects are being executed on a "Fast Track" the shortening of time during the design improves the quality of information available at the start of construction. Too often in the past Construction Contractors have been made to start work with limited information and thus not able to plan the safest method of working.

Plot Plans, Area Classification, and Instrument Integration.

All forms of construction work need the structure(s) or building(s) to be laid out so that emergency services, transport vehicles and maintenance equipment (cranes, elevating platforms, forklift trucks, waste disposal vehicles) can gain access and where practicable pedestrians and vehicles are kept separate. Where flammable vapours are likely to be present (Process vents, Storage Tank Vents, Tanker loading / discharge points) The size of area round the source are marked on plot plans to mark the boundary between the presence of vapours above and below their flammable limits. The ever-increasing use of computer controlled systems both for process control and building services management require drawings detailing all the control systems to be reviewed.

For the various reviews, checklists are copied from the electronic document database. The chairman of the review completes the checklists and minutes the actions for progress after the review meeting. Minutes are now recorded in an action tracking database. Assignment of an action can lead to an E-Mail being sent to a member of the project team / client representative. The member assigned the action enters the database, records the action taken, changes the action from open to completed and sends an E Mail back to the minutes co-ordinator. The completed actions, approved by the Project safety co-ordinator together with the minutes of the review can be included in the Safety File handed over to the Client on completion of the Construction Work. Reviews are often carried out after Construction Work has commenced and the completion of the actions may require the input from the construction site, the site may be included in the E-Mails and access to the database.

3D CAD / Tagging of Modules

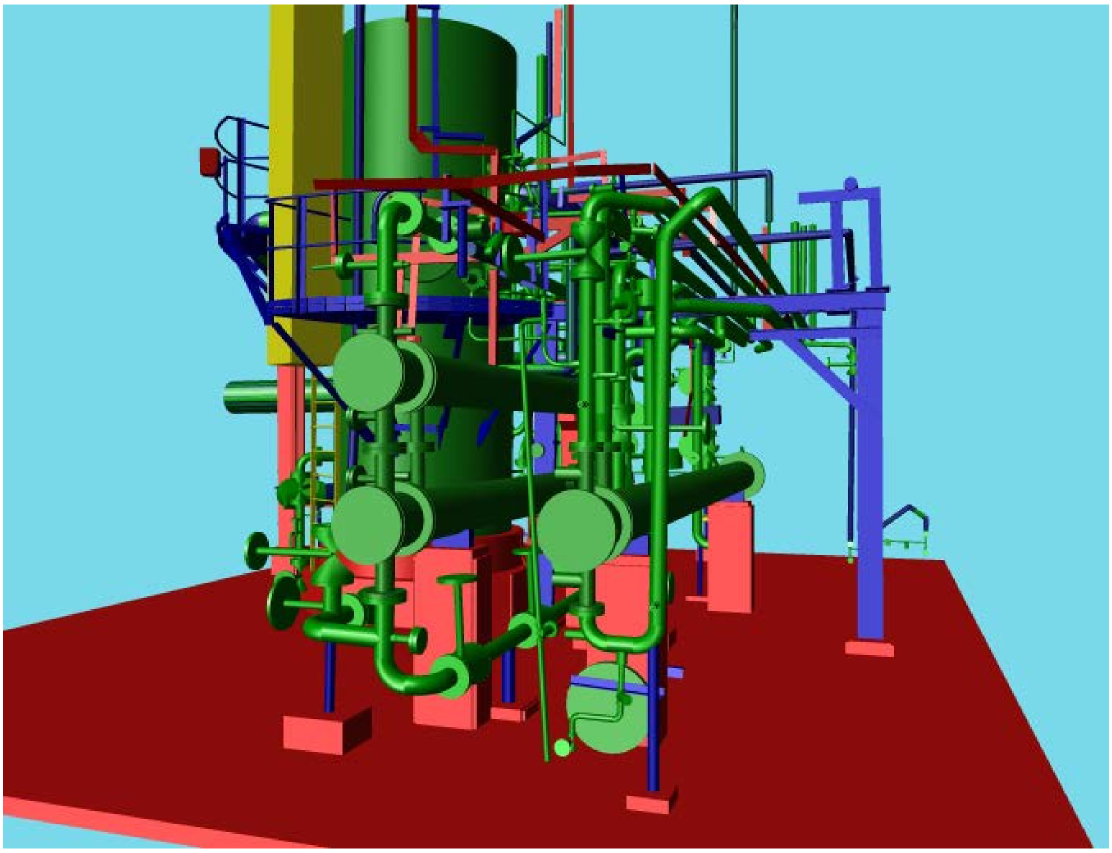
Prior to the expanded use of computers it was common to build large plastic models for process plant and wood / plastic models for buildings. The model making could employ two or more model makers for a considerable period of time and take up a large space for the model making. Model makers used sharp knives, flammable materials, glues and paints, which required a separate model making room with fume extractors. The introduction of 3D Computer Aided Design (CAD) models has removed the hazards of model making.

Having developed the model, the review team from the designers and the clients operational and maintenance staff can look at the model displayed on a large screen. The equipment and the surrounding structures and pipework / cable trays can be viewed from above, below and any point of the compass. Any item requiring further attention can be tagged on the screen with a consecutive number. The key requirement of the designers to mitigate risks is greatly facilitated, as the CAD models are very similar to the real full-scale structure. (An example of a digital photograph and the related CAD model are shown in Figure 1). The model is not restricted to local structures; they may include services running for long distances across clients' sites.

Having agreed the final design, at a late stage in the design, the model is instructed to print off detailed drawings for construction. The model, transferred to a Compact Disc can be delivered to the client, who can then use the model on his own computers for staff training, for site generated "As built" records and for further construction work.

Figure 1
Digital Photo of exchanger area.

Computer Generated Three Dimensional Model of exchanger area.



CDM Risk Assessment/ Residual Risks*:*

Although the use of CAD modelling is revolutionising the activity of design risk assessment and risk mitigation, there still remains a need to input into the Pre Construction Safety Plan details of any residual risks. The recording of risk assessments and residual risks can also be entered into “word processing programs” and printed off for issue with Safety Plans and Safety Files. The “word processed” documents can be placed into an electronic directory for use on future stages of the project or other projects. On a recent refinery refurbishment over 30 Safety Plans were issued to tendering work package contractors and some 25 risk assessments / residual risk forms issued. (See figure 2). The completed forms are now available as a database for future projects and the revision of construction procedures.

Figure 2 Risk Assessment / Residual Risk Forms (Included in Pre Construction Safety Plan)

<table>
<tr><td colspan="4">Design Company</td><td colspan="3">Project:
Project No</td><td>Discipline
Civil/Structural</td><td colspan="3">Rev 1</td></tr>
<tr><td colspan="4">RISK ASSESSMENT FORM
46121</td><td colspan="2">Ref No 702C01</td><td>Compiled By</td><td>Signature</td><td colspan="3">Date</td></tr>
<tr><td colspan="6">Work Package
CIVIL WORK Piling / Foundations</td><td>Lead Engineer</td><td>Signature</td><td colspan="3">Date</td></tr>
<tr><td></td><td></td><td colspan="3">Initial Rating</td><td colspan="2"></td><td>Page of</td><td colspan="3">Revised Rating</td></tr>
<tr><td>No</td><td>Hazard/Activity</td><td>P</td><td>S</td><td>Risk P x S</td><td colspan="2">Design Action to Mitigate Risk</td><td>Residual Risk</td><td>P</td><td>S</td><td>Risk PxS</td></tr>
<tr><td>1</td><td><u>Being trapped.</u>
• Trench / embankment collapse</td><td>6</td><td>6</td><td>36</td><td colspan="2">• Detail adequate drainage supplied for slopes.
• Slopes angles to be detailed</td><td>Contractor not providing adequate shoring in trenches.</td><td>2</td><td>5</td><td>10</td></tr>
<tr><td>2</td><td><u>Overhead/under ground services</u>
• Electric shock during excavations /plant movements.</td><td>6</td><td>5</td><td>30</td><td colspan="2">Designer to gather appropriate data and design best layouts to minimise interface.</td><td>Contractor not confirming locations and providing adequate precautions/ warnings</td><td>2</td><td>5</td><td>10</td></tr>
<tr><td>3</td><td>Trip injury
• Piling reinforcement</td><td>5</td><td>5</td><td>25</td><td colspan="2">Specify rebar end protection</td><td>Rubber caps not provided</td><td>2</td><td>3</td><td>6</td></tr>
<tr><td></td><td>ACCEPT / REJECT Revised Rating</td><td colspan="5">Project Co-ordinator/ Project Engineer
Name Signature</td><td colspan="4">Planning Supervisor
Name Signature</td></tr>
<tr><td colspan="11">P=Probability, S= Severity, Score each from 1 to 10, P x S Score 1 to 100 If revised rating accepted complete residual risk form, If rating rejected Discipline Engineer to revise design action and revise second rating Low Risk Score 0 to 9 seldom occur, Medium Risk Score 10 to 20 Frequently occur, High Risk Score 21 to 100 certain/near certain to occur.</td></tr>
</table>

DESIGN RESIDUAL RISK FORM	
Project	Design Company
Project No	Discipline **Civil**
(A) Residual Risk No 702C-RR01	Item **Piling Work/Foundations**
(B)Raised by Discipline Engineer________________________Date__________ Approved by Lead Engineer ________________________ Date___________	
(C) Hazard related to	
Hazardous Material Operations Emergency Shutdown **Construction** Maintenance Decommissioning/Demolition Commissioning/Start-up Normal Shutdown 0ther________________	
[D] Description of Hazard (*Several hazards may be listed on this form, Identify item Nos. from Risk Assessment Form)***Ref No 702C01** CONSTRUCTION 1.Trench / embankment collapse 2 Overhead / Underground Services 3 Trip injury on exposed reinforcement bars	
[E] Risk Mitigation CONSTRUCTION 1. Contractor to ensure slopes battered or shuttering provided to prevent collapse. 2. Contractor to confirm location of overhead and buried services and provide adequate precautions / warning. Permit to Excavate to be applied. 3. Piling contractor to provide rubber caps over reinforcement or similar protection.. .	
(F) Accepted by Project SHE Co-ordinator / Project Engineer________________ Date____________ Accepted by Planning Supervisor ______________________ Date____________	

Constructability Reviews

Constructability is an ongoing activity during the design stage of a project, but specific reviews are useful when planning high-risk activities, such as the use of very large cranes.

The use of simple 2D computer models for determining the location of cranes for heavy lifts and the positions of trailers carrying the loads to be lifted in and out can significantly reduce the time taken to undertake the lifting operation. There is a saving in the time / hire cost of crane(s) and, where lifting is in the centre of busy towns, the time over which roads may need to be closed to pedestrian and vehicle traffic.

The production of a portfolio of computer generated views for use in training and informing construction supervisors and workers improves the efficiency of construction work. It also assists in motivating site workers to plan their daily activities and thus avoid accidents to them or others affected by their work.

REPORTS, RECORDS, PLANS, FILES, DRAWINGS, CAD MODELS

Summarising the reviews detailed earlier, after the initial outlay for the computers, software, network connections and staff training, a quick means of reference for designers, suppliers, constructors, plant operations and maintenance staff is now available. Speedily updated and reviewed when changes made. (Flixborough!). Communications are enhanced, experience shared and accidents avoided.

INTRANET / INTERNET

The networking of computers also gives access to a wide range of supporting information: -Legislation, International/ National / Company Standards, News Bulletins, Procedures, Manuals, Review Checklists, Lessons Learned / Work Improvements accessible to workforce at offices and work / construction sites through worldwide computer links.

COST BENEFITS

The use of computerised design systems and the functionality available to the designers have enabled saving in project schedule and cost. Reductions in field rework from an industry norm of 5% to less than 1%, reductions in schedule of 8 weeks over an 18 month project, minimal material surpluses, reduced design rework and productivity enhancements inherent with these system all add up to savings in the region of 15% on the overall project total installed cost. The schedule savings further increase the benefits to clients with respect to time to market of their products and thus enhanced revenues. Computer systems including 3D CAD may be used effectively on both small and major projects.

CONCLUSIONS

- Enhanced risk mitigation during design.
- Reduced accidents during construction work
- Quick communication with personnel working from different locations.and fast transfer of current information between locations
- Quicker revision and issue of up to date information.
- Electronic archiving of information with rapid access to records

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COMMUNICATION: THE KEY TO DESIGNING SAFELY

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ABSTRACT

We have come a long way since the first recordings of workplace related incidents and over the years the UK construction industry has witnessed a steady decline in the number of accidents and fatalities. However, compared to other industries these figures are still unacceptably high. Formally, safety held its domain firmly within the construction phase where it was perceived most accidents were caused. Over the last twenty-five years fundamental changes to UK legislation have seen health and safety being addressed in the design phase. The initial response is that the CDM Regulations have raised awareness of health and safety issues throughout the industry. However, for many designers the application of such regulations is intuitive and relies on the attitude and behaviour of the designers towards safety and their ability to communicate the identifiable risks effectively. Encouraging designers to think safely will only flourish in an environment where technical information is freely available. This paper will address some of the problems associated with CDM and look at the importance of communication and possible ways of enhancing information flow.

Keywords: Communication, design safety

INTRODUCTION

The CIB/ECI Design for Safety and Health conference has drawn on research from a wide geographical area. From the USA and South Africa to Japan and Europe and although the inference is on Designing for Safety and Health, the issues generated range from design for construction, operation, maintenance and temporary works to tools and techniques, education and training and legal aspects associated with health and safety. Whilst causational criteria may hold the route to many a solution it is communication that binds together all the influencing issues. If we are to address workforce safety issues from ergonomics to long term health problems we must begin with open communication and dissemination of information.

A TIME FOR CHANGE

Fundamental changes to UK H&S legislation began with the Health and Safety at Work Act (1974), which provided a comprehensive system for dealing with health and safety in the workplace and the hazards created by it. Subsequent European Directives have reinforced this and currently the driving influence in construction has been the introduction of the Tempory and Mobile Sites Directive 92/57/EEC. In its UK guise the CDM Regulations (1994) represented a significant development, in that it widened the scope of previous legislation by imposing new legal responsibilities on clients and designers. In addition, the Health and Safety Executive has published supporting documentation in the form of guidance notes, which address specific elements of work.

The industry recognises that CDM has delivered important intangibles such as raised awareness of health and safety issues both on and off site. However, data for tangible benefits including a reduction in the number of accidents and lost time or measurably safer buildings, is either anecdotal or unproven (Knutt, 2000). HSE statistics are inconclusive in that over the four-year period 1993/4 -1997/8, although there has been a drop in fatalities, major accidents have risen from 2627 to 4619. The HSE suggests that this is a result of an increased number of accidents reported, which previously has been as low as 46% and changes to accident reporting legislation (RIDDOR 1995) have widened the parameters for inclusion within the major accidents category. However accident statistics only address half of the issue, while asbestos, repetitive strain injury and other long term health complaints go unnoticed. Similarly have we to wait ten years to find out if the regulations have addressed maintenance and demolition criteria?

Article 14 of the Temporary and Mobile Sites Directive requires the UK to report every four years to the European Commission on the practical implementation of the provisions of the Directive. Since their introduction there have been numerous reports and studies into their effectiveness including Experiences of CDM (CIRIA 1997) and The Consultancy Company Report (HSE 1997). They found that many designers are unsure of their duties and the extent of risk assessment required and that as a result, the practices of designers are affected by their lack of familiarity with the requirements. “There are undoubtedly problems in understanding and applying the regulations and as yet, only a minority of participants are fully competent at their roles” (CIRIA 1997)

One of the more recent surveys carried out by CONIAC (1999) highlighted a number of industry-recognised deficiencies:

- The principles of the CDM Regulations are right, but there are problems with implementation.
- Most clients irrespective of size are unaware of or do not want to know about the Regulations.
- The role of the Planning Supervisor is often not seen to ‘add value’ to health and safety

- Although there have been some improvements, designers’ knowledge of and commitment to health and safety is limited
- There was strong support for the principles of assessing competence and resources, but concern about the excessive paperwork that is generated
- Pre-Tender and construction phase health and safety plans are often generic with little or no relationship to particular construction projects. In addition plans are too large and not used on site
- There is insufficient training in project related health and safety and little consultation with the workforce
- The should be a high level of visible enforcement of the regulations with more publicised prosecutions

The key issues in relation to designers were listed as follows:

- Many designers are not complying with Regulation 13, which places a duty on the designer to ensure that any design he prepares avoids foreseeable risk.
- Designer’s knowledge of health and safety is limited and many are not interested
- Designers use off the shelf material, which causes problems. Designers should do more to question what cause problems
- HSE must encourage more effective communication between designers and contractors at an early stage

Whilst all of the aforementioned issues need to be addressed, of particular importance is the level of designer knowledge and commitment to health and safety, for one of the intrinsic factors of risk assessment is the elimination of risk at source. In order to do this designers must have the technical knowledge or access to it, to be able to identify the potential risks that their designs create for the workforce.

PENALTIES OR OWN GOALS?

If the risk of accidents and their associated costs in lost time and insurance premiums, are not a sufficient motivating factor, then a UK Court of Appeal ruling made in November 1998 recommended that in future, fines must be large enough to impact on those who manage a company (and their shareholders). Whilst fines should avoid the risk of causing bankruptcy there may be cases where an offence is so serious that the defendant ought not to be in business.

Table 1: Average fines imposed per industrial sector (HSE, 1998)

Sector	**Construction**		**Manufacturing**		**Service**	
Year	1993/94	1997/98	1993/94	1997/98	1993/94	1997/98
Average Fine	£3384	£3173	£2973	£5895	£3939	£5726
No. of Convictions	415	533	585	432	217	212

In the UK construction sector although the number of convictions has increased, the average fine imposed has decreased. The reverse of which is true for both the manufacturing and service sectors. The Ramsgate Walkway collapse and Heathrow tunnel collapse are high profile cases where stiffer penalties have been levied. Ironically the £1 Million fine against the two Swedish firms involved in the design and fabrication of the walkway and the Australian tunnelling consultant found partly responsible for the Express link collapse have 'walked away without paying the fine' as criminal fines cannot be pursued outside the country (Thompson, 2000). In addition a Court of Appeal ruling made in January 2000 uncovered a loophole in the regulations, which resulted in designers escaping responsibility for the work of their contractors.

More recently The Sunday Times exposed an internal HSE document entitled Public Expenditure Review 2000 that highlighted the financial crisis the Executive is in. Currently only 8.4% of the 35,000 major injury recorded in the country are scrutinised and as a result of government capping and >10% of its budget being spent on the Paddington rail crash (which resulted in no prosecutions), the HSE is faced with shelving more investigations (Editorial 2000). This turmoil created by the Treasury and the Judiciary is not helping designers or the industry. It is therefore crucial that the industry is more self-regulating.

THE NEED FOR COMMUNICATION DURING DESIGN

Numerous government and stakeholder-sponsored studies on the culture and operation of the UK construction industry have been conducted. These reports have acknowledged that communication and information flow during design have a major impact on the performance of construction projects. The most recent, the Egan Report (1998) identified a number of shortcomings, which included:

"*too much time and effort is spent in construction on site, trying to make designs work in practice.... which is indicative of a fundamental malaise in the industry - the separation of design from the rest of the project process*."

"*there has to be a significant re-balancing of the typical project so that all these issues are given much more prominence in the design and planning stage before anything happens on site*"

"*designers should work in close collaboration with the other participants in the project process. They must understand more clearly how components are manufactured and assembled*."

From a designer point of view the lack of knowledge of construction materials, processes and techniques used in the industry is of major concern. This is compounded by the inability to identify and eliminate risks. Associated with the introduction of the CDM Regulations is the necessity to keep abreast of new and revised health and safety legislation, for in designing safely and being able to carry out risk assessments, designers will now need to know the parameters which govern work tasks, operations and materials used. This is no small accomplishment for, since their introduction, numerous regulations, approved codes of practice and revised statutes have been implemented, not to mention new materials each of which have particular handling characteristics and COSHH requirements. It is hardly surprising therefore that some in the industry have been slow to adopt such practices. Thus, to a large extent the application of such regulations is intuitive and relies on the attitude and behaviour of the designers towards safety and their ability to communicate the identifiable risks effectively.

Atkinson (1999), who carried out an empirical study of 107 UK construction industry practitioners, found that communication was the highest rated factor to affect human error. He further suggested that a comprehensive examination of patterns of communication is required. Similarly, in a detailed survey of 38 construction companies in Hong Kong, K.W. Wong et al (1999) found that communication was the most important factor affecting safety performance on construction sites and second most important affecting the company as a whole.

BS 7000 (Design Management Systems) recommends that a communication policy should be enforced within the design process to ensure those involved are informed about everything relevant/pertinent to the task in hand. It also suggests that lines of communication should not be confused with lines of authority and that communication may legitimately occur in any direction through an organisational structure.

These two recommendations appear to contradict current UK practice. Various reports on the practical implementation of the CDM Regulations have suggested that the information generated tends to be generic and voluminous. The reasons for this are unclear, however it is thought that because designers are not confident on how to demonstrate compliance with the requirements, they include all the information pertinent to the project regardless of its relevance to health and safety.

In addition lines of communication are controlled by the procurement system adopted for the project and are not as flexible as suggested the British Standard. For example under the UK's JCT 80 lump sum traditional form of contract, theoretically the design is complete before contractors and specialists have been appointed allowing little or no opportunity to communicate before the design is complete. Under JCT 87 the Management Contractor is the only party to have exclusive contact with specialists, not the designers. This clearly shows difficulties for the designers if they require information from specialists.

Thus communication during the design phase is a major factor governing the performance of construction projects. It also appears that designers are ill equipped to satisfy all the technical requirements within a project especially in relation to health and safety. In addition it seems that communication is hindered by inflexible procurement contracts and lack of relevant information.

INFORMATION AVAILABILITY FOR DESIGN DEVELOPMENT

Design entails the combination and balance of ideas generated by the design team, which should reflect the needs of the clients brief. Much design involves the use of basic components and materials in new and different ways within the constraints of the planning and standardised tolerances. There is no single underlying method or system used in the creation of a design, most design strategies are re-iterative and consist of the generation of several potential solutions or hypotheses, which are evaluated, refined and even combined until an acceptable solution is created (Gray *et al* 1993).

Within this environment of evolution and change, health and safety can often become of secondary importance to the more immediately demanding requirements, which are usually determined by the client. This is not merely an oversight, information is traditionally scarce during the early stages of design, and in some cases information is simply not available. As yet there is little information on designing safely in construction. While there is a surfeit of published material relating to the design of plant, process, offshore and nuclear industries, construction has been largely ignored. The introduction of the CDM Regulations brought new requirements for designers to consider safety. These regulations however are not prescriptive and as a result implementation has been inconstant.

It must be remembered however that safety issues are not the only new regulations or practices to be introduced. Construction is constantly developing, in as much as green issues embodied energy, and other environmental criteria have also come to the fore. At the same time existing controls are continuing to evolve, for example, Part L of the Building Regulations, Party Wall Agreements, etc. all of which have an impact on the designers. It appears that designers have been able to adapt and incorporate these new and evolved changes into design because ultimately they are based on existing knowledge of incorporation e.g. in a number if cases a change of material specification will address the issue.

Designers are apparently unaware that the same is true of some safety issues. For example between 1986 and 1992 the category that caused the largest number of fatalities in the UK was associated with roof work and within that criteria 56% (83 deaths) were associated with falling through fragile material including roof lights, asbestos panels, thin metal liner panels and wooden access staging. HSE statistics for 1999 still show that the roof-work trade contributes 20% of all construction fatalities. A simple change in specification at the design stage may have saved many of these unnecessary deaths.

Thus it appears that there is little information during the design stage in relation to the project, there is little information on designing safely in construction, certain procurement routes hinder communication flow and to a certain extent designers are unaware, unwilling or unable to seek technical solutions from elsewhere. One proposed solution is through education, certainly of those who are currently in training but also those in professional practice through continual professional development and their professional bodies. This however is of limited use as we have previously acknowledged that construction is constantly developing techniques and materials and availing ourselves with all that happens in construction through CPD is unrealistic.

Feedback or project dissection meetings would also be a valuable contributor. Before the end of the defects liability period the project stakeholders could discuss the pros and cons on the design, construction and initial maintenance aspects of the project. This would provide an invaluable source of information to the designer on the safety, buildability and maintenance of their designs. However in practice although feedback has for a long time been advocated (e.g. Part M of the UK's RIBA Plan of Work) industry has seen fit to ignore the opportunity.

Seeking information from specialist contractors would appear on paper to be the most beneficial. Specialists are more than likely to be at the forefront of technology within their discipline, certainly more aware than most designers. They have knowledge on initial and life cycle costing, buildability, maintainability and possibly demolition / decommissioning. In fact numerous reports have found that early incorporation of specialist knowledge enhances overall project performance. However, just as fragmentation of the industry has helped evolve the diversity of specialist contactors it has also created barriers. Design liability would strictly lie with the specialist if they were to provide design information. Thus specialists would have to charge for the information, if not for their time, certainly for the liability insurance, which in turn would increase the design costs. Whether the additional design costs outweigh the benefits of safety, buildability and maintainability not to mention other factors would be open to debate.

CONCLUSIONS

Health and Safety need to be considered as a part of project risk along side programme, environment and budget etc. For only when all risks are considered and controlled as an integral part of the project will benefits be seen? Designing for safety at an early stage would lead to greater appreciation of project risk and its proper apportionment. It would also lead to increased buildability and thereby its associated benefits: quality, production rates, reduced delays etc. If safety cannot be sold on its own merits then selling it as a means of achieving other requirements may be the most convincing method for its incorporation and inclusion. Feedback, more flexible procurement contracts, Education and CPD, communication with specialists and longer design times would all aid the designer in communication and dissemination of project information.

This paper clearly indicates that insufficient knowledge is dedicated to the implementation of safety procedures during the design phase. This paper concludes that there is much need for improvement. Designers need more information about the projects' potential hazards at a time when information is traditionally scarce. The ability to effectively communicate design intentions is critical for safe construction and maintenance operations. Research into the communication of safety during design is therefore crucial for future improvements.

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PROPOSAL FOR AN INTEGRATED SAFETY & HEALTH DESIGN SYSTEM

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ABSTRACT

This paper reports on a study carried out at the ISET Dept of the Milan Polytechnic concerning the integration of safety planning activities in routine building design operations. A preliminary step involved observing the situation at Italian construction sites during the first two years after the introduction of the European directive 92/57/EEC in Italy in March 1997 (Italian legislative decree n. 494/1996).

A graphic interface was subsequently developed with a view to promoting co-operation between the different specialists involved at the project preparation stage, based on a net browser application tool, called SHIDS (Safety and Health Integrated Design System). A brief account is given of the system framework, the aim of which is to manage information flows and apply integration procedures in a precise and straightforward way.

Keywords: Integrated design system, health and safety

INTRODUCTION

The Directives issued by the Council of the European Communities between 1989 and 1992 concerning safety and health matters on construction sites have drawn attention to the related management aspects. Potential technical and working solutions for the problems involved have been studied in relation to the single stages of each production process in order to identify hazardous events or pathological situations for workers and thus integrate the necessary safety and health elements in the working procedures.

In the building industry, it is difficult to achieve this on account of the clear distinction, in most cases, between the design stage (the client) and the development stage (the contractor). Moreover, the execution phase is often characterised by the concomitant presence of more than one employer operating at the same site. In such a situation, the main problem is represented by the integration of the safety measures specified in the working procedures of single contractors (developed in non-specific contexts) with specific requirements described by the client's design documents, including the safety and health plan for the construction. The research described in this paper began with an assessment of the situation at Italian construction sites during the first two years of application of the European directive 92/57/EEC, which came into force in Italy in March 1997 (Italian legislative decree n. 494/1996). Briefly, this assessment revealed inadequacies in terms of: a) process organisation; b) the preparation of complete and congruent design documents; c) the integration of building design and safety planning activities (on the client's side); the workers' compliance with safety procedures arranged specifically for them (on the contractor's side). One of the reasons for investigating this situation emerged from recent Italian legislation on public works (law n. 415/1998), that introduced a northern European management approach to building activities and an accurate description of the design documents and their content.

RELATIONSHIPS BETWEEN THE SAFETY & HEALTH PLAN AND OTHER DESIGN DOCUMENTS

In order to investigate the relationships between the design documents and the safety and health plan, the latter has been divided into seven main sections: A) Site Environmental Conditions; B) Construction Site Requirements; C) Works Description and Planning; D) Safety Operating Schedules; E) Risk Assessment for Duties; F) Co-ordination Rules; G) Bill for Safety.

The executive design framework described by the legislation includes the following basic documents: 1) General Report; 2) Master Plan; 3) Technical Reports; 4) Executive Drawings; 5) Technical Specifications; 6) Bill of Quantities; 7) General Specifications; 8) Contract Scheme.

Figure 1 shows a block diagram of the main relationships between the previously-listed project elements.

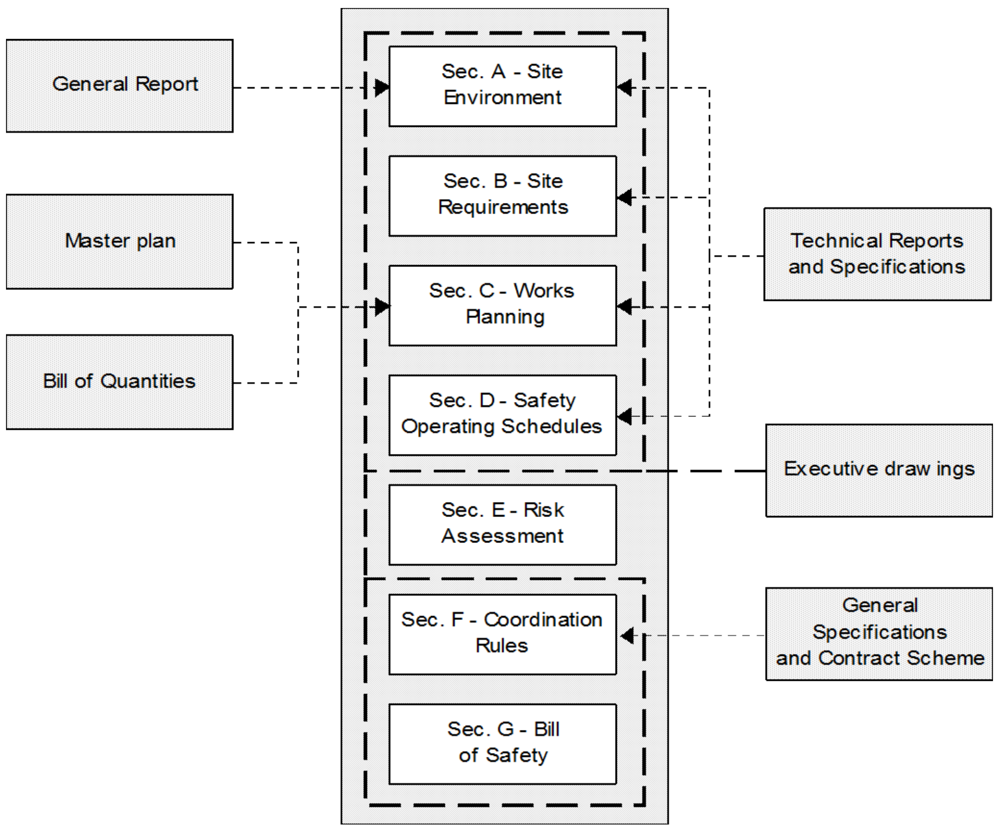

Figure 1 – Relationships between the design documents and the safety and health plan

By law, the integration and congruence between these different elements has to be achieved by preparing "Project Guidelines", in which the project manager specifies: a) starting conditions, aims and strategies; requirements and needs; b) technical rules, specific local restrictions, environmental impact evaluations and technical requirements; c) design activity stages, sequences and times; the accuracy of the design drawings and reports, depending on the type and dimensions of the works involved; d) charge limits, cost estimates, financial sources and realization system. The investigation has particularly emphasised that the integration between design activities and safety planning is lacking because the latter is usually confined to the end of the design process, in total contrast with the aims of the European directive and the Italian decree n. 494/1996. That is why the Master Plan for the project should indicate specific steps in the design process, each accompanied by the corresponding safety plan's states of advancement.

In order to reinforce the efficacy of the relationships between design and the safety plan in terms of integration and congruence, this study emphasised the importance of a tool - as simple as it is novel in the Italian context - called "Technical Design Bibliography", which is compiled on the basis of elements contained in the specific technical reference material on which every designer relies (e.g. technical or safety files on products, standard working codes, standard technical specifications, scientific and specialist publications). The elements selected for the project form the database for each executive design document, shared between all those involved in the design and safety planning activities. It is on these "bibliographical" elements of the project that the relationship and comparison between the different technical roles (designer and safety co-ordinator) is based, as shown in Figure 2.

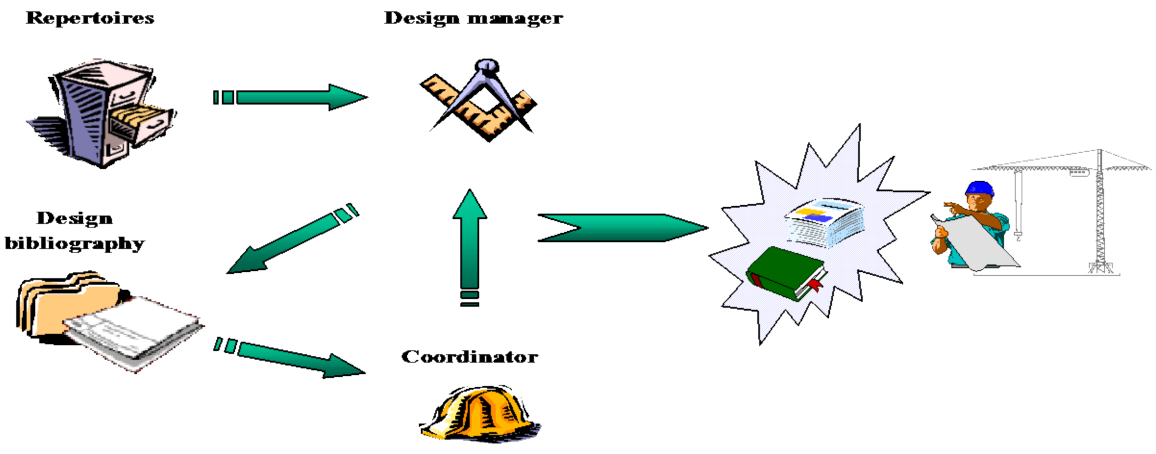

Figure 2 – Design reference material as a tool for exchanges of ideas between different specialists

SUBJECTS INVOLVED IN THE INTEGRATED SAFETY AND HEALTH SYSTEM

To simplify the building process, the study characterised three main figures involved during the design stage and taking part in the work group for integrating the procedures described below.

The Project Manager is the person appointed by the client to manage the building process in order to optimise the quality, economic and temporal aspects: he identifies needs and resources for managing the building process, organises and supervises their use, co-ordinates different types of expertise, and assesses final results. Of course, a technical staff of specialists supports the Project Manager in these activities. In particular, to emphasise design and safety integration, the Project Manager is assumed to coincide with the Project Supervisor as defined in the European directive.

The Design Manager is the person appointed by the client or by the Project Manager to co-ordinate each type of expertise involved in the design process.
Finally, the Co-ordinator at the Project Preparation Stage (CPPS) is appointed by the client or Project Manager to ensure the workers' safety and health. He analyses technical and operating design solutions, identifies and assesses risks for workers during the execution stage, also focusing on any coexistence and interference between different employers on construction sites.

THE FOUR STAGES IN THE INTEGRATED SAFETY AND HEALTH SYSTEM

The pattern for integrating safety and health with the design documents has been divided into four stages:

- creation of the work group;
- set-up;
- warm-up;
- work-up.

The aim of the first stage is to develop a contact between the parties involved in the process (Project Manager, Design Manager and Co-ordinator at the Project Preparation Stage).

The set-up stage aims to establish conventions for governing relationships within the work group and for design document production and handling, by means of a suitable number of briefings presided over by the Project Manager. At the end of the set-up stage, the Project Manager prepares a set-up document (containing a record of all the previously-decided conventions and rules) against which the proper implementation of the subsequent activities is measured.

The warm-up stage is for making the input data from the Project Guidelines and pre-design documents clear to each member of the work group and for delivering output data for the subsequent executive design stage and safety and health integration process. The Project Manager, Design Manager and Co-ordinator of the Project

Preparation Stage are obliged to take part in every warm-up briefing, at the end of which the Project Manager draws up the design plan. This document, in the form of a Gantt diagram organised on two levels of activities and recapitulations, contains information on the timing of the design activities, meetings, briefings, milestones for checking the design documents and recording progress: it represents a management tool for the work-up stage.

The work-up stage involves the actual development of the design and safety planning activities. It consists in a set of individual and group activities presided over by the Project Manager around a virtual work table, where the Project Manager, Design Manager and Co-ordinator exchange information in order to ensure the conformity of the executive design to the requirements expressed in the Project Guidelines and in the pre-design and set-up documents, and also to apply an integrated safety and health system. There are three main activities involved, i.e. data and document exchange between work group members, co-ordination and control by the Project Manager of the other two parties involved; safety integration between the Co-ordinator and Design Manager.

SAFETY AND HEALTH INTEGRATION PROCEDURES

To manage this four-stage process, a set of standardised, specific procedures has been envisaged, together with a system of warnings, specifications and restrictions governing the interfacing between the parties involved and the design documents produced. The procedural pattern demands two kinds of tool for its application, which have been developed in this study:

- records of every application of a procedure, to be kept throughout the process;
- check-lists (essential for guiding the analysis of design documents to acquire the necessary information and ensure the procedural correctness of the integration process).

The procedures aim to achieve the following targets:

- co-ordination of the safety plan with the other design documents;
- compliance of the executive design with established requirements;
- clarity, comprehensibility and consistency between documents;
- conformity of document lay-out;
- optimisation of the depth of investigation;
- improvements in single intellectual performance levels.

In addition to standard procedures applicable to all four stages of the integration process, specific procedures applicable to the work-up stage include:

- completing the design bibliography procedure;
- the safety integration procedure.

These procedures are used for the mutual integration between the Co-ordinator and Design Manager, under the Project Manager's supervision, as shown in the diagram in Figure 3.

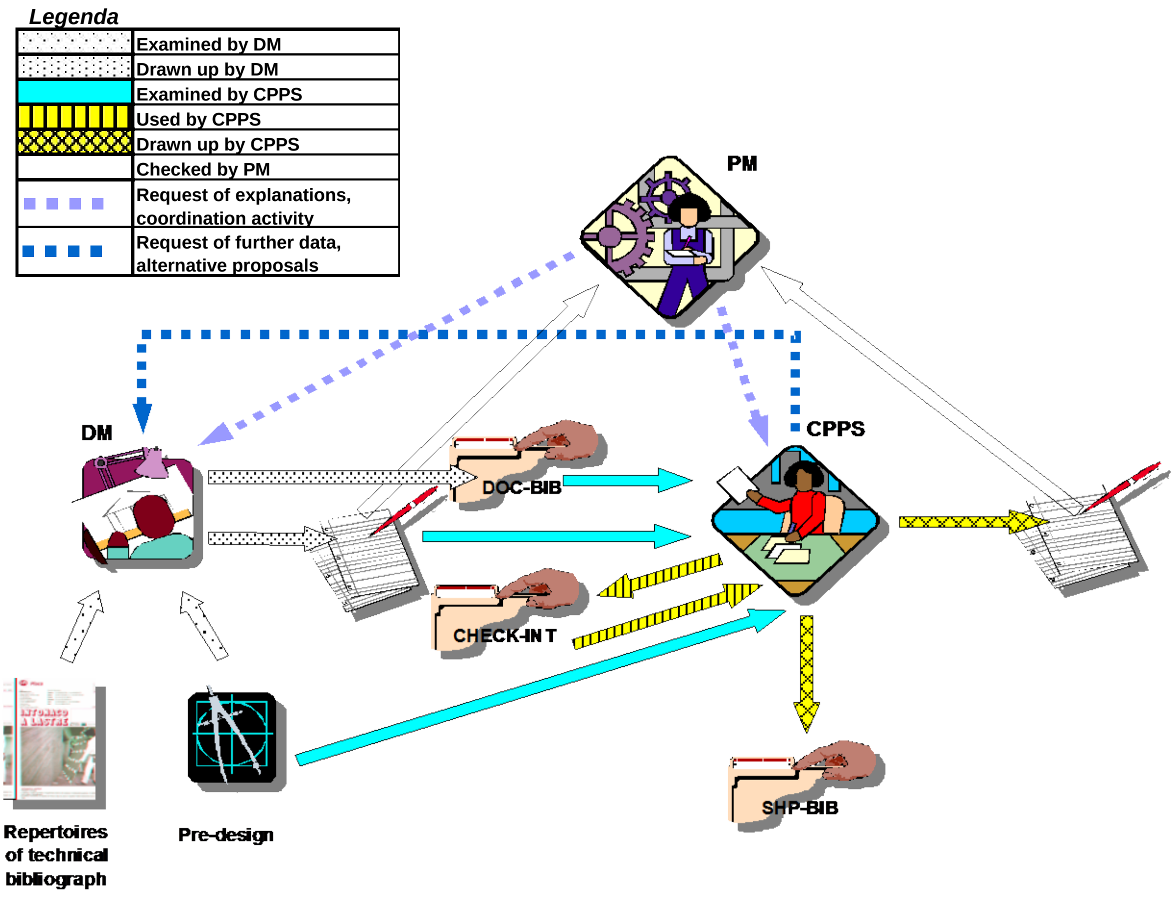

Figure 3 – Safety and health integration system

The Design Manager examines the pre-design documents, as specified at the warm-up stage, consults the technical reference material and specifies the reference material for each design document issued. He applies an established procedure, filling in a check-list and making a record of the references so that the Co-ordinator can examine the design documents complete with the references. After gaining an understanding of the pre-design problems during the warm-up stage and starting to elaborate sections A and B of the safety and health plan on the basis of the design documents, the Co-ordinator can also apply the specific safety integration procedure for each design document received from the Design Manager during the work-up stage. This enables the Co-ordinator to refer to the bibliographic material attached to the design documents and to complete the checklists with safety data for integration with the executive design documents. Then the Co-ordinator can elaborate the remaining sections of the safety and health plan, again making a record of the references relating to each section of the plan.

The process of integrating the safety plan in the executive design thus takes place through a comparison between the two sets of design documents, one drawn up by the Design Manager and the other by the Co-ordinator at Project Preparation stage. The process consists in information flows from the DM to the CPPS (e.g. when the Co-ordinator asks for further information about some design aspect) and in design integration flows from the CPPS to the DM (e.g. when the Co-ordinator proposes alternative construction or technological design solutions). This entire process is co-ordinated and supervised by the Project Manager.

THE COMPUTER-AIDED SAFETY AND HEALTH INTEGRATED DESIGN SYSTEM

To optimise the three-way pattern of relationships between Project Manager, Design Manager and Co-ordinator at the Project Preparation Stage, a graphic interface called the Safety and Health Integrated Design System (SHIDS) has been developed, configured like a web site comprising three modules:

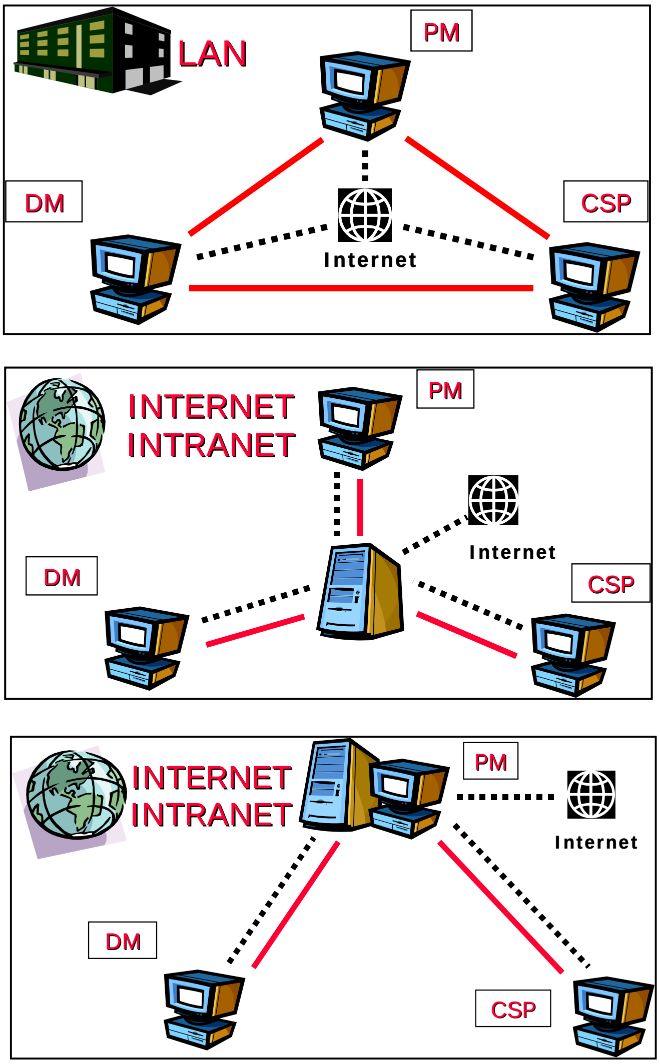

Figure 4 – Intranet and Internet patterns between work group members.

- Project Manager module;
- Design Manager module;
- Co-ordinator module.

The SHIDS and its three modules enable each work group member to access a virtual net (figure 4) by means of a password (attributed at the beginning of work-up stage to protect the information) and to update the documents being produced in real time.

In particular, the Design Manager and Co-ordinator can:

- send and receive elaborated and reviewed design documents and reference material over the web;
- compile, record and store the check-lists for each design document;
- examineset-up documents, design plans, minutes of briefings;
- send and receive general communications;

all by means of hypertextual links on a PC, using a web page type of format, as shown in figures 5, 6 and 7 ("SIIPS" is the Italian acronym for SHIDS").

The potential of SHIDS was tested on the Masters courses for Safety Co-ordinators organised in 1999 in Reggio Calabria (Italy) by Prof. Arie Gottfried (ISET Dept – Milan Polytechnic) with the support of the author of this paper and the local Professional Association of Architects. A computer application was tested for developing safety planning activities called "Computer Aided Safety and Health Planning" (CASHP). This is used as a local application for the Co-ordinator module in the SHIDS. So CASHP and SHIDS are essentially two "web tools" for developing complementary working procedures, the former becoming a part of the latter. At the end of each Masters course, the specialists taking part (designers, works managers, safety co-ordinators, construction site managers, project managers) completed a questionnaire measuring their appreciation of the CASHP. Opinions were expressed on the following parameters:

- ease of consultation;
- evidence of logical links;
- intuitive nature of module pages;
- ease of using module pages;
- improvement in single subject’s knowledge

and were very satisfactory (20% of opinions were “excellent”; 55% were “good”) and, given the methodological analogies between the two graphic interfaces, this judgement can also be attributed to the SHIDS.

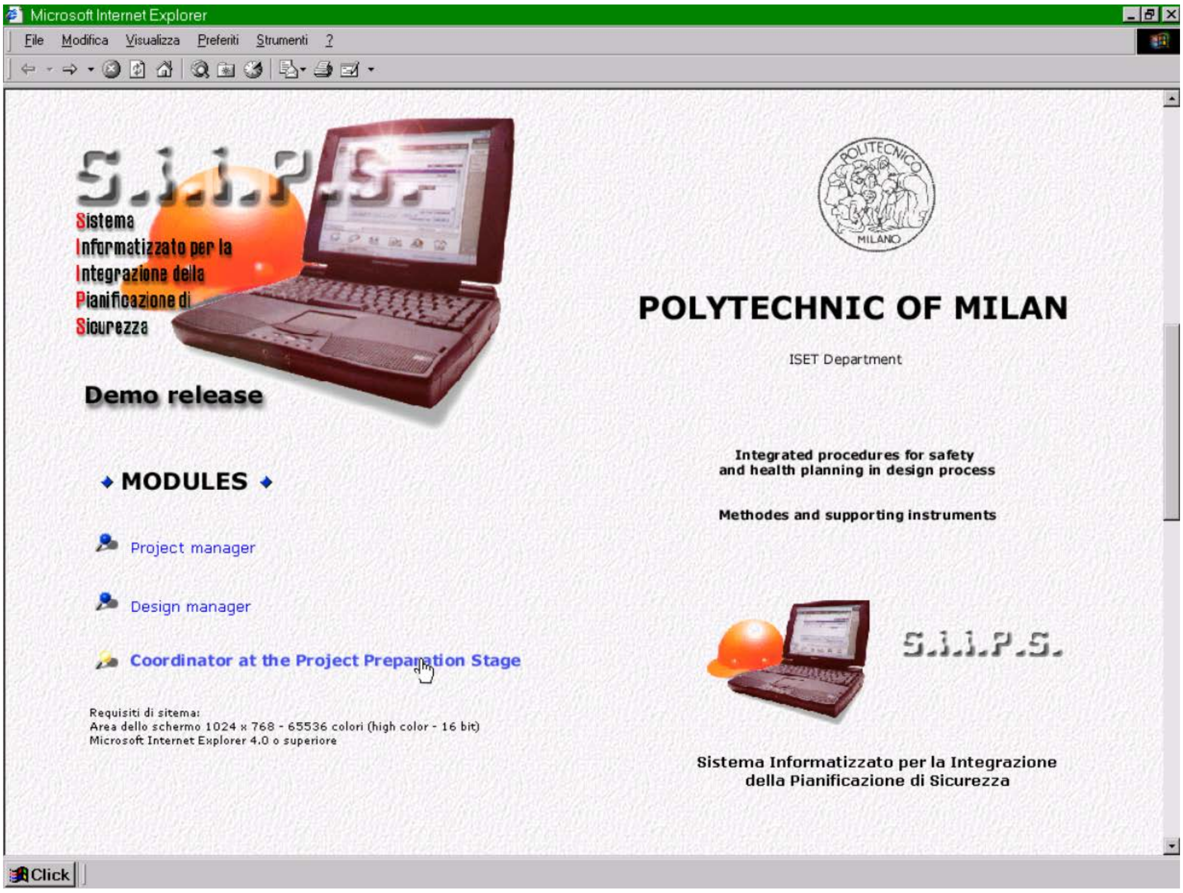

Figure 5 – SHIDS home page

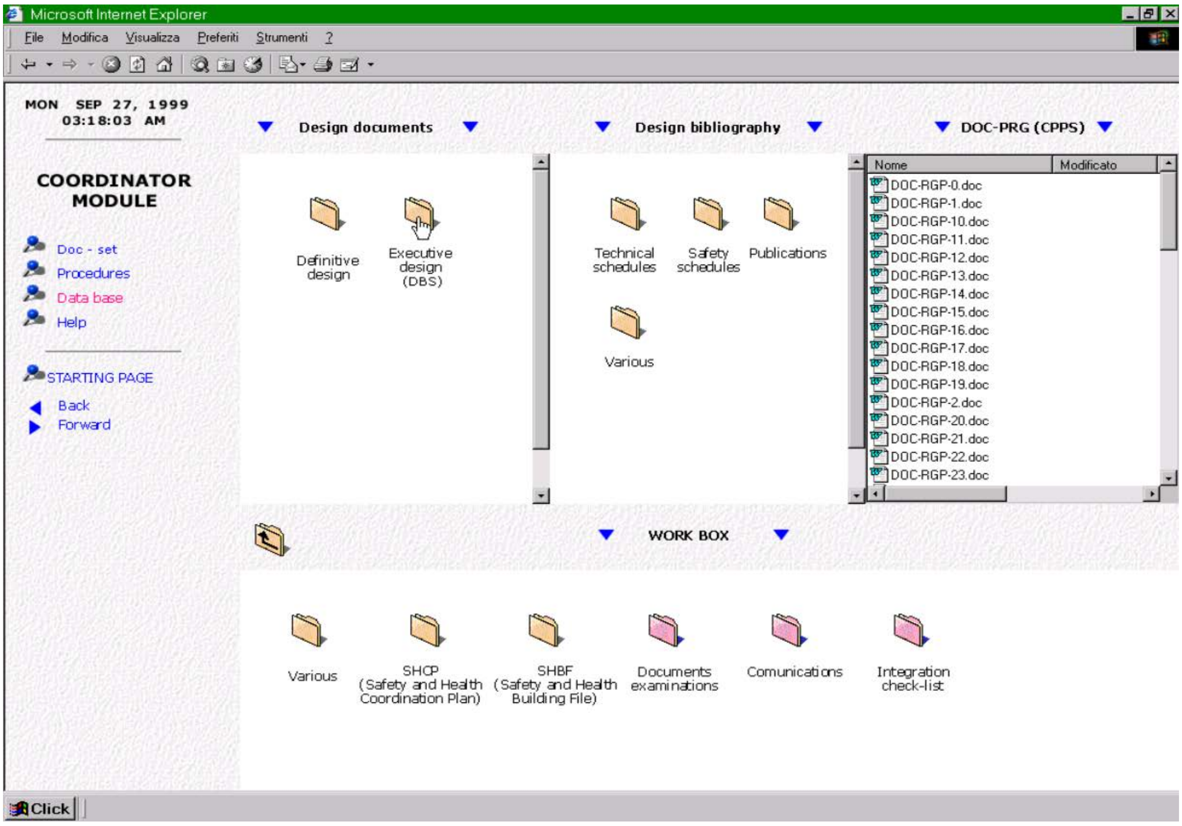

Figure 6 – SHIDS Co-ordinator module - database page

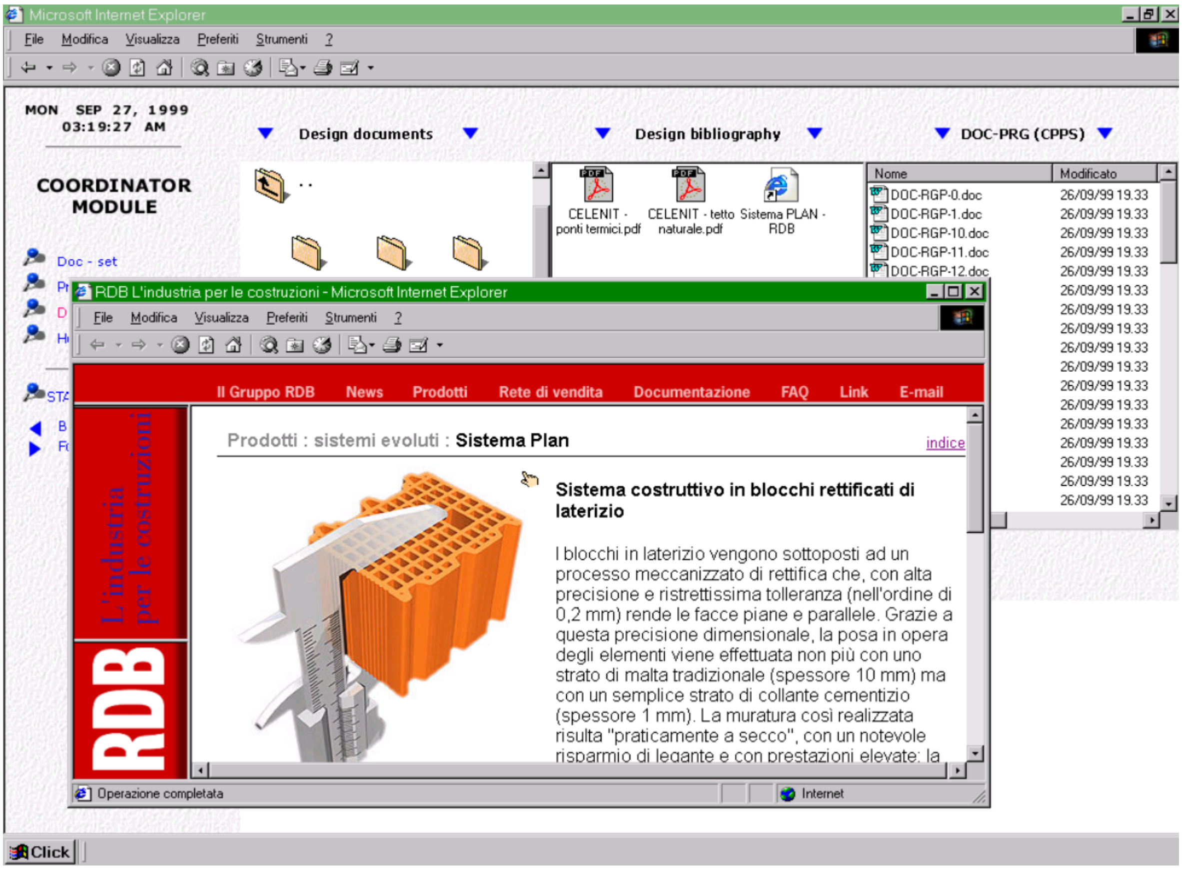

Figure 7 – SHIDS Co-ordinator module –technical references for design

CONCLUSION

Procedures for integrating safety and health planning activities represent an essential tool in order to draw up congruous documents for contract tenders and thus achieve the predicted quality level for the final building. Such a conception of quality in the building process also includes the quality of life for people involved in the construction work and those responsible subsequently for its maintenance. In this sense, quality is achieved through:

- active co-operation between the different specialists involved in an integrated system;
- the completion of the building contract with a body of readily-accessible design reference material during the executive stage for each design document;
- the use of computer applications for managing information flows and applying precise and straightforward co-ordination procedures.

TOMORROW'S DESIGNERS: WE BUILD FROM HERE…

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ABSTRACT

The introduction of health and safety philosophy to aspiring professionals in their formative years will have a fundamental effect upon their ability and willingness to embrace this important element during their later working life. It is a fact that the matter has been largely ignored in the past but recent changes to UK legislation have forced the issue.

This paper reviews the requirements of those regulatory bodies responsible for setting standards for the UK construction related disciplines, in respect of undergraduate courses and initial professional training and experience. It also considers the challenges to Universities in delivering such material. The paper concludes with a number of recommendations for assisting and improving the approach to considering health and safety in a consistent manner across the industry.

Keywords: education, health and safety, graduates, training, undergraduates

INTRODUCTION

Today's designers have, on the whole, not yet demonstrated a grasp of the need for designing for health and safety. This need arises not only to satisfy legislation, but also because attention to health, safety and welfare makes good business sense and will also assist in achieving many of the improvements sought by those trying to improve the industry generally, such as Egan[2]. The link between such initiatives and good safety management is well established and has been commented on in this particular respect.[1]

Tomorrow's designers however should be different. It is believed they will generally have a far more positive attitude and willingness to consider health and safety issues as an integral part of the design process.

However, although most will have graduated with degrees containing an element of health and safety risk concept and management - an area almost universally missing from historical courses-there is a noticeable difference in emphasis between the various disciplines.

In this paper the principal professions applicable to the UK construction industry have been considered ie Civil, Structural and Building Services Engineers, together with Architects, Building and Quantity Surveyors.
The intent therefore is to set the scene for other papers in this conference relating to the design process and its improvement in the UK by:

- Outlining the requirements of the regulatory bodies in respect to the professional pathway,
- Illustrating how the Institutions have approached the issue of health and safety,
- Reviewing the means by which Universities are implementing this subject,
- Highlighting the key issues.

This paper does not promulgate an original theory; instead the aim is to collate current practice and initiate debate as to how best to introduce health and safety to the aspiring professional.

COMPONENTS OF A PROFESSIONAL PATH

For all the disciplines mentioned above, the pathway to becoming a professional involves three stages:

An educational base: usually an accredited degree,
A period of initial professional development: some 3-4 years in practice on an approved training scheme; those not on such a scheme are involved in a longer period.
A test of competence and commitment assessment: in all cases involving some form of interview and presentation of work examples.

These paths are regulated in order to maintain standards; the various bodies involved are shown in Table 1.

Discipline	**Institution**	**Regulatory Body**
Civil Engineering	Institution of Civil Engineers(ICE)	Engineering Council(EC)
Structural Engineering	Institution of Structural Engineers(ISE)	Engineering Council(EC)
Building Services Engineering	Chartered Institution of Building Services Engineers(CIBSE)	Engineering Council(EC)
Architecture	Royal Institute of British Architects(RIBA)	Architects Registration Board(ARB)
Surveying	Royal Institution of Chartered Surveyors(RICS)	RICS

The Engineering Council (EC) was established by Royal Charter to enhance education in, and to promote the science and practice of, engineering. Its requirements in respect of the routes to registration as a Chartered Engineer, Incorporated Engineer and Engineering Technician are set out in Standards and Routes Towards Registration(SARTOR)[3].

Nominated bodies(such as ICE, ISE, CIBSE) may be licensed by the EC to accredit programmes of education and initial professional development providing the standards meet the requirements of SARTOR

The three engineering institutions mentioned in the paragraph above have established the Joint Board of Moderators (JBM) and the Joint Accreditation Panel(JAP) in order to maintain and strengthen links with UK Universities and to ensure the adequacy of first degree standards for Chartered and Incorporated Engineers respectively.

The RICS and RIBA also accredit degree courses. The former through the Surveyors Courses Board (SCB), the latter in conjunction with the Architects Registration Board(ARB)

In all cases degree courses are moderated by visiting teams on a 5-7 year cycle.

Educational Base

For many years there was no requirement for engineering degrees to contain a health and safety element. This was a bone of contention amongst many practitioners. The Third Edition of SARTOR however included for the first time specific demands on universities to include health and safety issues within the curriculum of engineering degrees although no guidance is given as to how or to what extent this should be realised. These requirements applied from September 1999.

The JBM has comprehensively picked up the baton and its requirements, covering engineering degrees, are the most comprehensive of all the accreditation bodies. These require:

'*A deep understanding of Health and Safety issues and the need to operate safe systems of work is mandatory for practising engineers and courses must expose students to the issues and need to extend the analysis to the legal requirements as well as risk analysis.'*

In addition, guidelines are available to Universities offering engineering degrees giving further detail to the above intent. These are included in Appendix A. The JBM seeks to improve these on an on going basis and welcomes feedback.

The Inter-Institutional Group for Health and Safety (comprised of members of the IChemE, ICE, IEE, IMechE, HSE, and the Hazards Forum) have also published helpful guidance[5] compatible with the JBM guidelines to further reinforce the message.

The RICS guidelines are more general:

'*Understand and apply Health and Safety Regulations in the context of the organisation*.'

Although health and safety is mentioned in this way it is left to Universities to decide how they include this subject; no further guidance is given.

The RIBA Outline Syllabus recognises that there is a need for an '*understanding of health and safety issues'.(*mentioned in respect of Part 1).

Of the five areas of study 'Constructional and Architectural Technologies' includes within its learning outcome the need for an understanding of-

'*hazards associated with materials and building'* (Part 1) and a '*working knowledge of health and safety Regulations and the professional responsibility with regard to the Construction(Design and Management) Regulations'* (Part 2).

The course content and the interpretation of the above is left to the schools.

Implementation by Universities
The teaching of health and safety by Universities is still in its infancy. The manner of its delivery and the depth of its teaching will inevitably be influenced by the guidelines of the relevant accreditation body. Hence there is likely to be some variation across the disciplines particularly in those areas where the interpretation and content is left to the University or School.

This new emphasis has significant implications for Universities and its success will depend upon appropriate and effective implementation.

HSE have recently conducted a scoping study of the teaching of health and safety within Universities using structured interviews[6]; the Executive Summary is enclosed in Appendix B as this raises a number of important points that deserve wide dissemination.

From the above one can observe that the issues facing Universities are:

- Available lecturing skill base
- The methodology for integration of health and safety into existing modules
- Provision of dedicated health and safety modules
- Curriculum time
- Provisions of teaching aids and general support.

If health and safety is to be taught by integration into existing subject matter(as it is believed it generally should be) the implication is that all lecturers need to be conversant with the subject matter.

Initial Professional Development
For this phase the requirements are again interpreted by individual Institutions so as to satisfy the generic requirements of their licensing bodies but, in sympathy with the undergraduate phase, they reflect the same differential emphasis.

The ICE training scheme includes a number of core objectives; the breadth of these encompasses the need to

'recognise the importance of, and taking responsibility for safety, to manage and apply safe systems of work, and to produce engineering solutions in compliance with regulations concerning safety and risk.'
The core objectives themselves follow this through by including

'by knowledge and understanding of current legislation and best practice, take responsibility for personal and collective safety'

The achievement of these objectives is decided by a Supervising Civil Engineer.

The ISE requires graduates to achieve core objectives which make specific reference to health and safety viz.

'…demonstrate an appreciation of the Law of the Construction Industry…particularly with respect to statutory legislation, health and safety legislation,…', and

'The Candidate should develop a knowledge of the role of hazard and risk assessments in avoiding or mitigating the potential risks posed by both construction materials and construction activities to site personnel, building users and the general public'.

There is also a general requirement for the Candidate to show:

'commitment to the public interest in all aspects of their work including…health, safety, risk…'

CIBSE also use the concept of objectives, some being applicable to all those within this phase, and others related to the particular field of services engineering within which the candidate is engaged. In respect of the former, and under the heading of 'Professional Background' there is the requirement to:

'C*omply with codes of practice on Risk and the Environment and manage and apply safe systems of work, taking responsibility for own and others' safety.*

Helpful guidance is given as to how this may be achieved.

The RICS, mirroring the approach in respect of the degree courses, is more generalist. Each field of Surveying includes various common and core competencies which are compulsory to all candidates. The common competencies include, under the banner of 'Business Skills' the same requirement as for degree courses, ie:

'*Understand and apply Health and Safety Regulations in the context of the organisation*.'

However the core competencies for 'Building Surveyors' and 'Project Management' do not contain any specific reference to health and safety in their definitions. 'Quantity Surveying' does include reference to health and safety via two of the compulsory competencies –

'*identify and appreciate …..regulations in the construction sector including reference to health and safety*.' and,
'*Apply principles of health and safety in practice.'*

Those aiming for RIBA status spend two periods in practice during their period of training; firstly following acquisition of their first degree(Part 1) and secondly following their second academic period.(Part 2).During these periods RIBA require *'an understanding of legislation on health and safety and its implication on design and construction'* to have been obtained.

Test of Competence
All disciplines have a form of competency test as a means of determining whether the candidate has achieved sufficient training and progression since graduation. This takes the form of an interview and submission of work experience details(apart from the Institution of Structural Engineers and the RIBA who also utilise a written paper) It is left to the Interviewers in all cases however to decide what subject matter should be examined or questioned.

COMMENTARY AND RECOMMENDATIONS

Notwithstanding the pressures on modern degree courses for ever more content, the basics of health and safety philosophy have a deserved place in all courses. This is not just because health and safety is about the well being of people; it is because good health and safety management is fundamental to the overall success of any project. It is, or should be, a core consideration. Good health and safety is good business, and good business is what one is trying to achieve in the long run.

At long last the engineering courses appear to have the framework in place; it is now down to the Universities to determine how they are going to deliver. This will take imagination and determination. It will also depend very much on the support afforded by the head of school.

It is noted that Architectural and Surveying courses appear to have less detailed emphasis placed on health and safety by their regulatory bodies compared to the engineering equivalent. The professionals originating from these courses often play central roles in the procurement process, and as duty holders under the CDM Regulations[4], and need to be fully aware and conversant with the health and safety ethic.

This differential emphasis between engineering and surveying/architecture is generally continued into the initial professional development stage, although much will depend upon the mentor's interpretation.

There is a concern also I suspect that some academics believe the subject to be of insufficient intellectual rigour. A close examination however will reveal that the core of health and safety thinking ie the assessment of risk and its management is key to the evaluation of designs, projects, laboratory work, and field exercises. It introduces clarity of thought and the experience of making decisions, based not on absolute criteria, but on the test of reasonableness.

The Health and Safety Executive(HSE) is able to play a key role in this scenario as it is the only common thread amongst the plethora of Institutions, Universities and other interest groups. Indeed one of the greatest obstacles is the number of well meaning but often unco-ordinated initiatives; trying to establish the complete picture is not easy.

Some recommendations are given below; these are not necessarily original but are restated because they have significant merit and are fundamental to progression.

1 Consideration could be given by the registration bodies of the RICS and RIBA as to whether their requirements in respect of health and safety will ensure adequate outcomes without further guidance, and generally whether all disciplines in the built environment should be to a more unified base. There is no apparent logic for such a degree of potential differentiation in a core subject area.

2 A sharing of aspirations and experiences should be encouraged between interested parties eg the Institutions(which have the ability to include academics) and the HSE. Perhaps this could be through existing groupings such as the Hazards Forum or the Inter -Institution Group for Health and Safety but expanded to include the RICS and RIBA.

3 Assistance should be given to Universities and Schools of Architecture to establish adequate course content and teaching aids. This could be by provision of training for University staff, generic course notes and case studies, and particularly the development of Web based teaching aids. Emphasis should be given to integrated teaching wherever possible.

4 The concept of the ‘champion’ for health and safety at each centre should be pursued.

5 HSE should consider how they could target literature and advice specifically towards undergraduates and those within the initial development phase. It would be expected that this would be mostly through web based data. They have an ideal opportunity to capture the hearts and minds of the future generation of professionals.

6 Further involvement of practitioners should be encouraged; those in industry have much to offer here, particularly in differentiating between theory and practical application.

CONCLUDING THOUGHTS

It is the author’s belief that future graduates have the potential for transforming the industry; there is the opportunity to instil in them the essential nature of health and safety; they will come with no baggage. They should be ready to champion the concept of designing for health and safety as an integral part of the design process.

For this to happen there needs to be a co-ordinated approach to its inclusion within the educational base and initial development phase of young professionals such that all those involved in the built environment start from a common base, at least in the round if not in the detail.

A facilitator is needed from amongst the many interested bodies to drive these proposals through. It is suggested that the HSE could play a leading role.

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4. **HSE:** *Construction(Design and Management) Regulations* 1994
5. **Inter-Institutional Group for Health and Safety:** Incorporating Safety, Health and Environmental Risk Issues in Undergraduate Engineering Courses.
6. **Lee JF:** Education of Undergraduate Engineers in Risk Concepts: Scoping Study. HSE.

Appendix A Guidelines for the teaching of Safety issues to Undergraduates (Annex C of the Guidance Document produced by the JBM)

Appendix B Executive Summary; HSE Scoping Study.(Ref 6)

Appendices are available from the author.

ABBREVIATIONS

Those abbreviations not given within the text include-

HSE	Health and Safety Executive
IChemE	Institution of Chemical Engineers
IEE	Institution of Electrical Engineers
IMechE	Institution of Mechanical Engineers

DESIGNING FOR SAFETY:
IT STARTS WITH EDUCATION

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ABSTRACT

Addressing construction site safety during the design phase requires designers to be knowledgeable about the concepts and practical aspects of designing for safety. Implementation of safety knowledge in the design is currently impeded due to the boundary established between design and construction in both education and practice. Facilitating designing for safety requires a change in the traditional designer mindset. For the construction industry, this change is best affected through education when the designers are learning their trade. Recent studies have led to the accumulation of design suggestions that can be implemented by a project design team with the intent of minimizing or eliminating construction site hazards. These design suggestions have been incorporated into a computer program that assists designers in recognizing project-specific safety hazards and incorporating the suggestions into the project design. The safety knowledge and program can be used effectively in the process to educate designers about how to incorporate safety in their designs. This paper describes how the knowledge and program might be beneficially used in designer education to promote and advance designing for construction site safety.

Key words: Construction, design, education, hazard, safety

INTRODUCTION

Construction industry practice has evolved into predominantly the two separate fields of design and construction. Within design, specialization has resulted in a profession composed of consultants, each representing a specific design discipline such as architecture, civil engineering, and mechanical engineering. The expertise provided by each discipline constitutes a unique subset of the entire knowledge required to design a project. By combining their knowledge, design consultants conceptualize, engineer, and record a complete design that is then given to a constructor to build. On the construction side, the work is organized by trade. Each trade's expertise is methodically applied to produce a completed product that reflects the intended design.

Industry organizations, governmental legislation, and standard practice have essentially established a boundary between design and construction by defining expected scopes of work and outlining professional duties. By outlining a realm of expertise and knowledge, design disciplines and construction trades place borders around their work. The borders both limit the work that the designers and contractors are expected to perform, and surround the work to which they are entitled. The borders are fortified contractually and positioned by standards of practice (Gambatese 1998).

The construction industry continues to be transformed by both internal and external factors. The boundary between design and construction, while sometimes appearing immovable, has been re-positioned following technological advancements, changing economic climates, and modified values and perceptions of design and construction. An example of a recent change that has occurred in the United States is the acceptance of revisions to the American Institute of Architect's (AIA) Document A201, General Conditions of the Contract for Construction. The revised document delegates a greater amount of the design responsibility to the constructor for certain design details. AIA instituted the change to reflect the customary practice of contractors and suppliers providing design details for particular systems, such as in the case of designing supports for mechanical and piping systems. This practice occurs when the constructor sits in a better position to design the system than the design professional. The document revisions resulted in a shift of the boundary between design and construction to formally expand the constructor's scope of work and responsibility.

The Need for Education

It is unrealistic to assume that a change to industry documents or practices will result in immediate action and results. The process of change takes time and effort by all parties involved. The change must first be viewed as beneficial and be accepted. Accepting change requires a shift in the industry's mindset, something that is often difficult to accomplish. Once the mindset is altered to welcome the change, a determination must be made of how to best implement the change. Implementing the change may require new skills, equipment, or material, which may take additional time and capital to acquire. In many cases, funds and expertise must be transferred from other core business areas or acquired from outside sources to implement the new developments. This transfer is often difficult to feasibly undertake for firms lacking substantial resources.

Accepting and implementing changes begins with education. If designers and constructors are to alter their practices, they must first learn about the change and how the change will affect them. They must understand how the change affects their business practices, day-to-day operations, and liability. It cannot be expected that the construction industry will immediately know how to implement suggested changes. Effective implementation requires education on related concepts, training of skills, and measures for evaluating results. It is important as well to understand what will happen if the change is not accepted or implemented.

Construction industry education is gained both in the classroom and on the job. For designers, education is primarily in school, while constructors learn their trade primarily on the jobsite. In many, if not all, instances the most effective means for initiating change is to make it part of one's initial education. If a new concept is learned as part of one's initial educational process, there is no need to overcome ingrained biases. The new concept is considered normal practice and implemented right from the start.

Designing for Safety

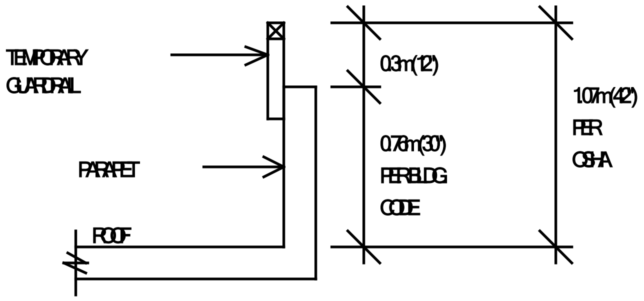
One area of the construction industry in which there has been change is the area of construction site safety. Traditionally, the constructor plays the major role in safety on a project. Designers have historically not been involved in any major effort to address safety on the construction site. When creating a design, the design professional focuses on safety of the "end user" of the facility such as the office worker, plant operator, or motorist. This focus is established in the building design codes which the designers are trained to follow. Construction worker safety is commonly left up to the constructor and governed by the safety and health regulations of a governmental agency such as the Occupational Safety and Health Administration (OSHA) in the United States.

Although their involvement in safety has been historically minimal, designers can play a major role in addressing safety on a jobsite. Designs created by architects and engineers influence the construction means and methods utilized and, therefore, affect construction site safety. Safety hazards that exist during construction are, to some extent, a result of the facility's design. Designers who realize the influence of their designs on construction safety can positively impact the level of safety on a project through their designs. It is in this manner that designers can play an effective role in safety.

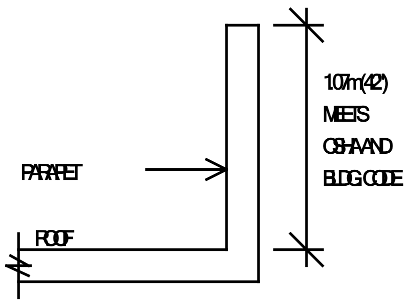
In the United States, designing for safety is currently not mandated and any efforts to address safety in the design phase are undertaken on a voluntary basis. Safety is addressed to a greater extent on design-build projects where the employees benefiting from the design are those of the same firm. Designers working on a design-bid-build project provide a number of reasons for not addressing safety in the design. These reasons include a designer's limited role on the project team; the lack of tools to assist them in identifying hazardous designs; a lack of education and training on how to address safety issues in the design; OSHA's placement of the responsibility for safety; and an attempt to minimize their liability exposure.

Unlike the United States, all companies working on projects in the European Union must address construction site safety as directed by EC directive 92/57/EEC. This legislation requires that safety hazards be addressed throughout planning and design in addition to the construction phase. While the legislation provides the mandate to consider safety, no specific means of how to address safety are provided in the Directive. Designers must still learn how to consider safety during the project's design phase.

A recent research study addressed the issue of how designers can modify their designs to improve construction site safety (Gambatese et al. 1997). The study involved the accumulation of best design practices which, when implemented in the project's design, help mitigate safety hazards during construction. The research effort led to the compilation of 430 best practices or "design suggestions." The suggestions relate to a wide variety of project components, construction site hazards, and project systems. Figure 1 shows an example of a design suggestion involving a parapet. The design suggestions were incorporated into a computer program, titled "Design for Construction Safety ToolBox", which assists designers in implementing the database of design suggestions. Based on information input about a project's design, the program provides potential safety hazards along with suggestions for modifying the design to eliminate the hazards.



(a) Common parapet design



(b) Parapet designed for safety

Figure 1. Parapet Design: Parapet meets (a) building code requirements, (b) OSHA and building code requirements

The research study, along with other studies on the same topic (Hinze 1992, 1994), concluded that there is a need to educate designers of the concepts of designing for safety. Designers need to be educated about the safety concerns related to their designs and the various means by which they can alter their designs to be safer. Without this education, designers will not accept the concept, know how to implement it, nor understand what results are expected.

BRINGING SAFETY INTO DESIGNER EDUCATION

The education and training of architects and engineers encompasses a wide variety of subjects. Traditional architectural and engineering education programs focus on providing knowledge of building systems and their design through classroom learning of design theory and engineering principles. On the job, designers are trained how to practically implement the design theories and principles. Each learning experience provides the necessary knowledge and skills expected of the designers in their work.

Architectural and engineering education generally begins with basic courses on analysis of systems and material properties. Once basic concepts and theory are grasped, the curricula continue with a focus on design. Initial design courses stress the fundamentals of design based on the learned concepts. Continued instruction on design focuses on meeting building code criteria. Architecture and engineering curricula typically conclude with additional courses that delve into industry practice such as construction contracts, project management practice, and engineering economics. A capstone design experience often rounds out the program to bring all parts of the curriculum together. With this educational background, designers begin working in their field and learn how to further implement the concepts in practice.

Effectively educating architects and engineers on the concepts of designing for safety requires special attention to the topic in design courses. Rather than creating an additional course that is solely devoted to designing for safety, it is appropriate to incorporate the topic into each design course within a curriculum. By addressing the topic in all design courses, the student learns that designing for safety is an integral part of the process as opposed to something that is external to the design process and which is added on to the design at some point in its development.

With the variety of design courses in a curriculum, one might ask in which courses should the design for safety concepts be stressed to have the greatest impact. Are there certain areas of design that have a greater impact on safety? Are there components of design which can be more easily modified to address safety? To have the greatest impact, course material should be developed that reflects where the design for safety suggestions are most applicable to the design and have the most impact on safety.

Where to Focus Design for Safety Education

One place to look for the designs that can have a great impact on safety is the database of design suggestions that has been developed as part of previous research studies. In reflection of the great diversity of the construction industry, the accumulated design suggestions reflect all types of design disciplines, project components, project systems, and construction site hazards. By analyzing the qualities of the accumulated design suggestions, a determination can be made as to where to concentrate education and training efforts for maximum impact on designing for safety.

The accumulated design suggestions can be sorted according to particular project components being designed. Table 1 shows that most of the suggestions addressed piping (18%), followed by electrical/instrumentation (14%), and mechanical/HVAC (13%). Components typically designed by the structural engineer (foundation, structural framing, slab-on-grade, floor, roof, stairs, ladders, ramps, walkways, and platforms) were addressed a total of 159 times (37%). Similarly, components typically within the architect's scope of work (furnishings, finishes, project layout, structure plan/elevation, doors, windows, handrails, and guardrails) were addressed a total of 85 times (20%).

On many projects, the architect also undertakes construction management tasks. That is, the architect not only designs such project features as the doors, windows, finishes, and space layout, but also performs construction management tasks such as managing the design consultants, coordinating the project drawings, and overseeing the project costs and schedule. If construction management components (general conditions, special provisions, and work schedule/sequence) are included with the architectural components, the number of suggestions increases to 157 (37%). Thus, when considering project components, education and training would be most appropriate for architects and structural engineers.

Table 1. Project Components Addressed by the Design for Safety Suggestions

Construction Site Hazard	Number of Times Addressed	% of Recorded Suggestions*
Piping	77	18
Electrical/Instrumentation	58	14
Mechanical/HVAC	55	13
Structural framing	52	12
Stairs, ladder, ramp	43	10
Work schedule/sequence	41	10
Slab-on-grade, floor, roof	35	8
Roads, paving, flatwork	32	7
General conditions/special provisions	31	7
Earthwork, sewer	24	6
Furnishings, finishes	20	5
Structure plan/elevation	20	5
Door, window	19	4
Foundation	18	4
Project layout	16	4
Tank, vessel	16	4
Technical specifications	13	3
Walkway, platform	11	3
Contract drawings	10	2
Handrail, guardrail	10	2
Total	601	

* Since suggestions may address more than one project component, the sum of these numbers (expressed as a % of the 430 recorded suggestions) exceeds 100.

All types of construction site hazards are addressed in the accumulated design suggestions. As shown in Table 2, the majority of the suggestions relate to falls (33%), followed by electrical shocks (14%), explosions (13%), and cave-ins (13%). Many falls on construction sites occur due to the structural and architectural scopes of work, i.e., the design of beams, columns, walls, stairways, ladders, etc. Thus, the resulting number of suggestions related to falls is expected based on the number of suggestions related to structural and architectural components as shown in Table 1.

Table 2. Construction Site Hazards Addressed by the Design for Safety Suggestions

Construction Site Hazard	Number of Times Addressed	% of Recorded Suggestions*
Falls	141	33
Electrical shock	60	14
Explosions	57	13
Cave-in	56	13
Fire	42	10
Toxic substances	38	9
Work area	34	8
Environment/Climate	31	7
Struck by objects	25	6
Vehicular traffic	25	6
Worker issues	21	5
On-line equipment	20	5
Obstructions	18	4
Heavy equipment	13	3
Confined space	10	2
Caught in/between	6	1
Lighting	5	1
Total	602	

* Since suggestions may address more than one safety hazard, the sum of these numbers (expressed as a % of the 430 recorded suggestions) exceeds 100.

The distribution of the number of construction site hazards addressed by the design suggestions is similar to OSHA's fatality statistics. OSHA's analysis of construction fatalities from 1985 to 1989 (OSHA 1990) revealed that the majority of fatalities (33%) were due to falls from elevation. This is comparable to the percentage of suggestions recorded that relate to fall hazards (33%). Similarly, the percentage of suggestions recorded that relate to electrical shock hazards (14%) is close to OSHA's reported electrocutions that accounted for 17% of all fatalities. Although OSHA statistics show that "struck by" and "caught in/between" hazards are responsible for 22% and 18% of the fatalities, respectively, similar high percentages are not reflected in the distribution of recorded suggestions. These differences may be due, in part, to the fact that these types of hazards are not generally caused by unsafe designs, but more frequently by worker oversight or error. The discrepancies could also be due to the vague interpretation of struck by and caught in/between fatalities recorded by OSHA since the additional categories reflected in Table 2 are not utilized by OSHA to describe the causes of accidents.

The database of design suggestions reveals that efforts to educate and train designers should primarily focus on the structural and architectural disciplines. It is these disciplines that will have the most to gain from the suggestion database. The design of structural and architectural components can be modified in many ways to help improve safety. If the design suggestions are implemented, it can be expected that falls from elevation can be significantly addressed through the design.

CONCLUSIONS

Addressing safety in the design requires focused attention to education and training of designers. Designers need to know the potential hazards as well as means for mitigating the hazards. Safety can be impacted to a great extent when structural engineers and architects incorporate safety into their designs. Therefore, it would be appropriate to concentrate design for safety education in such courses as design of concrete, steel, masonry, and timber structures, and foundation engineering. By focusing on these courses, there are more opportunities to modify the design to improve safety, and the impact on safety performance would be greater.

To incorporate designing for safety into academic courses, faculty can generate discussions of the different design suggestions when considering various design options. The suggestions can be presented at the time when students learn to design specific components. This learning could be facilitated through mock constructability reviews that focus on safety. The computer program Design for Construction Safety ToolBox could be used as a useful tool for discussing design modifications. The program also provides a means for learning what safety hazards might be expected on a site. It is with this type of education that designers can understand how their designs affect safety and ultimately play a significant role in safety on a project team.

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EDUCATION AND TRAINING IN THE BUILDING PROCESS AND INTEGRATION OF SAFETY DISCIPLINES: THE ITALIAN EXPERIENCE

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ABSTRACT

Designing of safety and designing for safety increasingly call for the integration of a basic knowledge of techniques of design and execution with specific education and training with the aim of preventing accidents and of safeguarding workers. However, this need inevitably comes up against an educational and training reality that views safety as a subject that is hard to introduce into the specific disciplines of university courses, and that is to be taught in integrative post-diploma and post-graduate courses or to be developed in the course of individual professional experience. After the modifications introduced into Italian interpretations of Community directives, the greater awareness of the roles assumed by the different operators in regard to safety problems calls for a profound re-organisation of teaching in the matter both at the level of upper-school and university education (university degree and university diploma courses) and at the level of training of building workers. The training courses for Co-ordinators must be "calibrated" to furnish the right intensity of information according to the type of qualification provided. Through an analysis of the above considerations, this paper presents a set of proposals for the organisation of training courses, from concrete teaching experiences carried out in an academic and institutional framework. There follows an examination of the content of these educational and training courses, both basic ones and refresher ones, for designers, Co-ordinators and contractors, as well as for building workers.

Keywords: Safety, education and training, Europe

INTRODUCTION

The main purpose of the present paper is to address the issue of safety training in its widest and most complete sense, and this without simply limiting our attention to the modifications to the Legislative Decree no.494/96. This decree is the Italian interpretation of the European Directive 92/57/EEC "*Implementation of minimum safety and health requirements at temporary or mobile construction sites*". In general, we should talk of two mutually complementary spheres: *training* and *qualification*. Training should concern all the actors involved in the building process: from the client to the designer, from the firm Technical Works Manager to those for the benefit of whom the mechanisms of safeguarding are actually designed, i.e., the workers. Qualification ought mainly to regard safety managers, i.e., the *Planning-phase Co-ordinators* and the *Execution-phase Co-ordinators*.

In order to combine these two training requirements, a possible approach would, for example, be a global training programme which links together the needs stemming from the Legislative Decree no.626/94 (on safety requirements mainly addressed to contractors) and from the Legislative Decree no.494/96 (addressed to the Client) so as to train all the operators involved in the process and to qualify the two Co-ordinator figures in a specific way.

TRAINING OF CO-ORDINATORS IN THE EUROPEAN UNION

The European Directive 92/57/EEC introduces the roles of the Planning-phase Co-ordinators and of the Execution-phase Co-ordinators who have to be appointed by the Client. The Planning-phase Coordinator is responsible for coordinating the general principles of safety and health in the planning phase and for drawing up the Health and Safety Plan and the Safety File. The Execution-phase Coordinator coordinates implementation of the general principles of prevention when the technical and/or organizational choices are made, with the purpose of planning the various phases of work on the construction site. He coordinates, then, the enforcement of the relevant provisions, adapts the Health and Safety plan (or sees to its being adapted) according to the evolution of the works and the possible modifications that may have been adopted. He is also responsible for organizing cooperation and coordination of activities between employers, as well as organizing exchange of information between them. The European Directive does not set down any modalities or contents, nor does it fix the duration of the training course for Safety Co-ordinators. The task of setting up specific courses or any form of instruction on the matter is left in practice to the various member countries of the European Union. Following the CIBW99 International Conference “Safety Coordination and Quality in Construction” held in Milan in June 1999, a summary of the situation regarding the training, qualification and recognised competence of Co-ordinators in some of the various Member States can now be drawn up.

Belgium

Training is provided at three different course levels :

- Basic level (60-hour course)
- Level 2 (210-hour course) for specialists in every sector and execution Co-ordinators with between 1 and 5 years’ practical experience, depending on the type of building site.
- Level 1 (410-hour course) for specialists in the various sectors and design Co-ordinators with between 1 and 5 years’ practical experience, depending on the type of building site.

The trainee must sit an examination at the end of the course.

Finland

The role of Safety Co-ordinator, as described in the European Directive, does not officially exist.

France

Safety Co-ordinators are trained at various course levels :

- 15 -day training course for level 1 ;
- 10 -day training course for level 2 ;
- two 3-day sessions plus 2 days for level 3.

The various levels follow on, one from the other. Planning-phase Co-ordinators with at least 5 years' professional experience must attend either a level 1 or level 2 course; if the Co-ordinator has at least 3 years' experience, then he or she must attend a level 3 course. Execution-phase Co-ordinator, with experience supervising the execution of building works (building management, site management, etc.), can obtain the necessary qualification by attending either a level 1 or level 2 course, with at least 5 years' experience, or a level 3 course with at least 3 years' experience.

Germany
No official courses have been set up, but one-week training courses are available.

Greece
A planning-phase Co-ordinator must be a qualified architect or engineer. A execution-phase Co-ordinator must have a school-leaving diploma or a degree in engineering.

Luxembourg
Even though the legislation does not envisage official training for Safety Co-ordinators, a person can qualify as both types of Co-ordinator having attended a course lasting 132 hours. Non-graduates cannot co-ordinate sites employing more than 1,500 men/days. To qualify simply as a planning-phase Co-ordinator, an 84-hour course is available.

THE LEGISLATIVE DECREE 494/96 AND ITS MODIFICATIONS FOR EDUCATION AND TRAINING IN ITALY

As interpreted from the European Directive 92/57/EEC, the Legislative Decree n. 494/96 contemplates two types of safety Co-ordinators: the *Planning-phase Co-ordinator* and the *Execution-phase Co-ordinator*. For both of them, a single training pathway is envisaged, without distinction between the different roles that they will perform. In order to be able to exercise their duties according to the legal requirements, the Co-ordinators must possess a specific safety certificate awarded by the Regional Authorities or, alternatively, by ISPESL (Higher Institute for Accident Prevention and Working Safety), the various professional associations, the National Council of Industrial (non-graduate) Engineers, the University, employers associations and worker trade-union associations, or by joint bodies set up in the building sector (Article 10, Clause 2).

The aforementioned certificate is not required of public-administration employees who perform the functions of Co-ordinators within the sphere of their own duties (Article 10, Clause 4) or of those holding a university certificate declaring that they have passed one or more examinations that are equivalent to the contents of Annex V of the Legislative Decree no.494/96 (Article 10, Clause 5). Annex V sets at 120 hours the duration of the training course, which must deal with the following subjects:

- current legislation on the matter;

- professional diseases;
- statistics on infringements of current rules and standards;
- risk assessment;
- standards of good practice and criteria of organization of the construction site;
- methodologies for drawing up safety and coordination plans.

The Legislative Decree no.528/99, that has partially modified the Legislative Decree no.494/96, has integrated Annex V regarding to the differentiations and contents of Safety Co-ordinators' training courses. Infact it is stated that, through some additional decrees that still have to be issued, those courses should be organised taking into account different levels of training and qualification related to the specific typology of site's works. Safety Co-ordinators will also be qualified for a specific range of construction works (those construction works will be listed by the above mentioned decrees). This qualification will depend on the Co-ordinators' competencies connected to their own academic degrees. The first issue of the Legislative Decree no.494/96 provided for a sort of "Transitional rules", envisaging a three-year transition period starting from the entry into effect of the decree (March 24, 1997). In this time interval, technicians who possessed a proven experience of at least 4 years in superintending other workers in matters of safety could attend a course of just 60 hours' duration. Now this transition period is no longer provided. As regards the themes to be dealt with in the training courses, in 1997 the Regional Authority of Lombardy resolved a provision entitled "Contents of Training, Organizational Standards and Modalities of Implementation of the Courses of Qualification for Planning-phase and Execution-phase Safety Co-ordinators".

As far as the areas of interest indicated in Annex V of the Legislative Decree no. 494/96 are concerned, an introductory module is added in this provision, which regards the specific characteristics of the building sector, the organization of the production process in all its phases, and the role performed by the Co-ordinator figures. The duration of the course, set by the Regional Authority, has been fixed at a minimum of 120 hours to be shared between theory and practice. The distribution of hours between theory and practice should be set down precisely according to the needs of the users of the specific course. On the basis of the sole obligation set down by law, i.e., attendance at the course, without there being any final examination set, periodical checks on learning are envisaged. The final certificate of attendance is to be issued to all those taking part, provided that they have not been absent for more than 10% of the total hours of duration of the course.

REFLECTIONS AND CONSIDERATIONS

The Leg. Decree no.494/96 prescribes in a sufficiently clear way the functions of the two types of Co-ordinators and their duties. However, it does not define in a unique and specific way the contents of the courses of qualification for the profession of Co-ordinator, and, in this sense, it is perhaps "overgenerous" in qualifying a conspicuous multiplicity of subjects. In addition to this the modifications to the Legislative Decree no.494/96 have extended the possibility to hold the role of Safety Co-ordinator to other graduates. These new professional requirements include the degree in Geology, Agriculture and Forestal Science. With all these degrees, including Architecture and

Engineering, the Co-ordinator must provide a certificate, issued by a Contractor or by a Client, proving to have been employed in the construction field for a period of at least one year. Certain considerations may be made in this regard. For instance, is it right to qualify the two Co-ordinator figures for the profession when the only obligation that these have is to attend a course that is without any final examination for ascertaining the actual competence of the person qualified?

A second reflection: are we certain that all the bodies mentioned in the Legislative Decree no.494/96 that are responsible for training and qualifying are in possession of the necessary teaching-training capacities and of the tools required? A further problem regards the *subjects* that may be qualified. If the approach is merely “bureaucratic”, it would be possible to allow all graduates and/or people holding a university diploma (in any subject?) to attend the courses, by introducing perhaps an entrance test and anyway a final examination. In this way, anybody who passes the final examination is qualified and is conscious (it is to be hoped) of his own responsibilities (and not only penal responsibilities). In the event where the aim is to train and qualify in a serious and responsible manner professionals who are capable of managing safety, health and hygiene in all that this implies, it would be necessary to revise practically the entire sphere of training and to structure the content of the courses according to the aims and the real needs of building.

PROPOSALS

The need to have available on the market a certain number of safety Co-ordinators on construction sites immediately after entry into effect of the Leg. Decree no.494/96 (March 24, 1997) has led to the introduction into the said decree of the transitional rules regarding in particular training and corresponding qualification (Article 19). More in general, at three years from enforcement of the Leg. Decree no.494/96, and after its modifications, it is possible to draw up the first assessments and hence propose an innovative approach to the matter.

Synergism between the Leg. Decree no.626/94 and the Leg. Decree no.494/96
Safety is to be approached as a whole in the framework of the building process; it is useless to split it into two separate spheres of requirements: on the one hand the client, and on the other the contractor. Even a safety plan drawn up in the best possible way would not be successful if the building firm were not well organized and its technicians and workers were not appropriately trained and informed. It is possible to consider training pathways that include disciplines that coincide for Co-ordinators and firm technicians. This seems to be even more necessary after the latest issue of the Leg. Decree no.494/96 where the Contractor is forced to draw up a Safety Operating Plan. This document co-ordinates the contents of the Health and Safety Plan, drawn up by the planning-phase Co-ordinator, with the Contractor’s site-specific organisation. There we should look forward to a complete educational and training pathway which integrates Safety Coordination in the planning phase with the site’s management in the execution phase. It is important to realise that, even if the Co-ordinators undergo excellent training and a complete and exhaustive safety Health and Plan exists, a gap may nevertheless be created by those workers who fail to follow instructions they are given or follow them incorrectly.

The construction process is broken up as a result of problems connected with the management of staff and interaction between operators working on site. Building workers must therefore not only be trained to perform their specific functions (for example, to operate a particular piece of equipment or construct specific items), but also to appreciate the varying aspects of a single site and relevant places of work. Workers must be made aware of safety as a philosophy whereby they ensure, not only the safety of the staff on site, but also establish conditions in which work can be carried out by others without creating risks Faced with the new requirements laid down by Leg. Decree no. 494/96 regarding the drawing up of an operative safety plan, employers will also have need of appropriate training. Not only for the purposes of drawing up the plan, but also to enable them to tackle safety problems well before work is initiated on site, passing on information and instructions to their staff (also via the staff put in charge) and thereby ensuring that work goes ahead correctly and safely. Therefore it should be recommended that all workers attend an integrated training course containing all the topics included in Leg. Decrees no.626/94 and no.494/96. This attendance should be also a contractor's requirement to employ new building workers.

Training pathways and subjects involved

The proposal is for different training pathways, or rather complementary pathways, both for the Planning-phase Co-ordinator and for the Execution-phase Co-ordinator. In a global teaching-training scenario, the Planning-phase Co-ordinator could be involved in only one part of this scenario, whilst the Execution-phase Co-ordinator, also in view of his more concrete responsibilities, ought to involve himself also in construction-site events in more operative terms. The admission to these courses of subjects who excluded until the new Decree (geologists, agronomists, etc.) could come about if, in the presence of well-structured courses (and certainly not those contained in Annex V of the Leg. Decree no.494/96) there were a final qualifying examination. In this way, it might be possible to set up two official registers: one for Planning-phase Co-ordinators, and one for Execution-phase Co-ordinators to certify the qualification of the professionals mentioned.

Content and duration of the course

It is thus possible to conceive of a course organized on more than one level. One first level of the course should contain subjects regarding rules and standards, technical problems, statistics on accidents, and programming of work and work management on the construction site. All this should be accompanied by practical activities inside the classroom concerning the themes referred to above, with corresponding guided visits to construction sites. This first level would be aimed at drawing up the Health and Safety Plan, which would be the subject of the final test. Passing the first level would mean qualification for performing the role of Planning-phase Co-ordinator. The duration of this part of the course could be 120 hours in all. The second level of the course would consist of practical training experiences to be carried out at building companies and/or firms with the aim of transferring the plan drawn up previously to the specific context of the company/construction site. In this second level of the course, those who have passed the first level, as well as firm technicians, could participate. The former, at the conclusion of this part, and following on a verification of their knowledge, would obtain qualification for the role of Execution-phase Co-ordinator; the latter would simply be awarded a certificate of attendance. The second-level course could last 60 hours. In this training phase, the subjects dealt with ought mainly to be aimed at risk assessment in “dynamic” terms and the drafting of an Safety Operating Plan according to the effective conditions of production and site management. Technicians and administrators belonging to public bodies could take part in both the first and the second training levels. The training of public clients can in this sense facilitate relationships and interfacing between these structures and the building-contractor world.

Training bodies
Having identified two levels of training course, there remains the problem of how to recognise the competence of the Organisations responsible for training and qualification activities. On what basis should such Organisations qualify and what sort of parameters should be applied in order to assess the validity of the courses attended?
Here are a few suggestions:
- defining the course levels on the basis of the trainee’s qualifications (pre-selection);
- establishing standard requisites for the selection of the training body;
- defining a minimum set of essential documentation to be given to the trainees;
- putting together a list of sponsors capable of guaranteeing the “validity” of the courses in question;
- maintaining contact with professional figures capable of putting together statistics regarding the usefulness of the contents of the course and the development of careers;
- establishing contacts with businesses willing to organise training visits and schemes as part of the courses in question.

In the transition period, from entry into effect of the Leg. Decree no. 494/96 up to the present day, it has been possible to admit an inhomogeneous and somewhat disorganized set of training bodies to the training of Co-ordinators. For the first level, which would lead to qualification of Planning-phase Co-ordinators, only bodies suitable by their very nature for teaching-training activities (universities and other academic and scholastic bodies already qualified by law) could be involved. The second level, aimed at the executive phase of the process, should involve, in addition to the first-level training structures, also the Territorial Joint Committee, building schools, and associations of firms, etc. The Regional Authority must not be involved directly as a training body; it could instead check, upstream, the teaching programmes of the various bodies proposing courses in safety whilst, downstream, it could form part of the final qualification examination boards. In addition, at a regional level, the programmes of the various teaching pathways could be compared and discussed in order to draw therefrom proposals for improvement. Along the same lines as mentioned so far, the part of the Leg. Decree no.494/96 that “exonerates” those who have attended equipollent courses at a degree level and/or university diploma level from the obligation to attend a qualification course would be acceptable if:
- the course were in any case qualifying only for the role of Planning-phase Co-ordinator;
- the university courses concerned were effectively equivalent in terms of content and number of hours.

SAFETY CO-ORDINATORS' COURSE STRUCTURE

1.	Legal Framework	1.a	Evolution & development of Safety, Health & Hygiene legal framework;
		1.b	Inspection & Control Institutions: aim, organisation and activities;
		1.c	Analysis of the Legislative decree no.626/94 in the Building & Construction sector
		1.d	Analysis of the Leg. decree no. 459/96 in the Building & Construction sector (implementation of the European directive 89/392/EEC)
		1.e	Analysis of the Legislative decree n. 494/96
		1.f	Legal aspects: the role of the Magistracy.
2.	Techniques & Applications	2.a	Construction site's equipment;
		2.b	Scaffolding and provisional equipment;
		2.c	Electrical installation;
		2.d	Formwork and scaffolding;
		2.e	Concrete batching plant, concrete mobile mixer;
		2.f	Excavations, open-cut mining, ground movements, geotech. problems;
		2.g	Assembly and disassembly of prefabricated elements;
		2.h	Assembly and disassembly of steel structural elements;
		2.i	Underground earthworks and tunnels;
		2.j	Road works;
		2.k	On site machines, equipment and tools;
		2.l	Assembly and disassembly of elevators and mobile ladders.
3.	Health & Hygiene	3.a	Professional diseases
		3.b	Noise and vibration exposure's risk;
		3.c	Asbestos' risk;
		3.d	Sanitary surveying, chemical and biological risk;
		3.e	Manual movements of loads.
4.	Design Scheduling And Management	4.a	The Operating design for the Safety & Coordination plan;
		4.b	Scheduling and programming construction works;
		4.c	Safety planning;
		4.d	Coordination planning;
		4.e	Design phase Coordination: applied cases;
		4.f	Execution phase Coordination: real experiences
		4.g	Risk assessment;
		4.h	Risk tendency and operators' safety motivations;
		4.i	Safety Costs
		4.j	The Building Maintenance Safety File;
		4.k	Accident statistic and violations;
		4.l	Collective protective disposals;
		4.m	Individual protective disposals.
5.	Practice Lessons	5.1	Safety legal framework in force;
		5.2	Case Studies;
		5.3	Construction site project and lay-out;
		5.4	Safety planning;
		5.5	Safety Coordination Plan's draw up.

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DESIGNING FOR THE LIFE CYCLE SAFETY OF FACILITIES

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ABSTRACT

Safety must be embodied in all aspects of a facility, beginning with the concept and design. The wholistic approach to design is for the life cycle of the facility to be taken into consideration. This also applies to safety considerations that must be addressed by the design. Historically, designers have taken safety into consideration in their design decisions, but this was often limited to the safety of the facility occupants. A wholistic approach to designing for safety is to address safety as it also applies to the construction workers, the workers who will maintain the facility, and those workers who will ultimately be involved in the disassembly or demolition of the facility. These are workers who are essential to the facility and their safety is well worth ensuring through judicious design decisions. When these are all taken into consideration in the facility design, the life cycle of the facility embodies safety. When examples are evaluated in how this can be achieved for each phase in the life of a facility, it becomes apparent that the design decisions that enhance safety for the construction workers also facilitate safety for maintenance workers and demolition workers as well. These decisions have a much broader impact on safety when all facility users, in all facility phases, are given thoughtful consideration.

Key words: Construction, demolition, design, maintenance, safety

INTRODUCTION

The design of physical structures has historically focused on the facility occupants. This is understandable since the project's very existence is generally attributable to the needs and initiative of the prospective facility users. These needs include the satisfaction of various functional criteria. Included among these criteria is the need to address the safety and well being of the facility occupants. This is often an innate concern of the designer. Safety is also at the core of the establishment of building codes that set the minimum safety standards that are to be met. The classical design approach and many building codes are primarily focused on the traditional facility users or occupants. In reality, there are other "users" that are often ignored. These include the construction workers who construct the facility and the maintenance workers who will maintain the facility. Lastly, the final occupants are those who will actually dismantle or demolish the facility. These are all individuals whose safety is worth ensuring. Thus, the suggestion is that designers consciously consider the safety of construction workers, maintenance workers, and demolition workers when design decisions are being made. An injury sustained by any of these parties should be avoided.

This paper will first show justification for designers to address the safety of all facility users. Examples will then be provided to show how the safety of each of these groups can be enhanced through thoughtful design decisions.

THE MORAL NEED TO ADDRESS SAFETY IN DESIGN

While the facility owner is the party generally paying for the design services, it is not appropriate for the designer to only consider the safety needs of the facility owner. Whenever design decisions can enhance the safety of others, this should be done.

Even some facility owners have become aware of the need to address safety in a broader design context. Many owners recognize that an injury that occurs to construction workers or maintenance workers or demolition workers might ultimately be paid by the owner. Indirectly, this is certainly the case when one considers that the insurance costs are passed on through to the owner. In addition, if a liability lawsuit arises as a result of an injury on the facility premises (regardless of the function or role of the injured party), the owner will invariably be named as a defendant in the lawsuit.

Since many injuries to construction workers, maintenance workers and demolition workers are potential liabilities for the facility owners; it is understandable that owners would want to eliminate jobsite injuries. From a purely financial perspective, it should become apparent that the owner's best interests are served by minimizing the chance of injuries to all parties that will utilize or occupy the owner's facility at some point in the life of the facility. While tort liability cases are decided with differing criteria in different countries, there is a general tenet that if one has the knowledge to assist in providing for the safety of others there is an obligation to use that knowledge.

Of course, there is a clear moral obligation to preserve the safety and health of facility occupants when one has the ability and means to do so. This certainly extends to all facility occupants, including construction workers, maintenance personnel, and demolition crews. A designer cannot defend opting for a less safe design option when lives are at stake.

If done properly, the design of a facility will embody safety for all those who will somehow interface with the facility during its life. Thus, the wholistic design approach will provide for safety of all, from the initial stages of the construction process through to the final deconstruction or demolition of the facility.

DESIGNING FOR THE SAFETY OF ALL

Various examples will be presented whereby the safety of different facility users can be better assured. Since traditional design approaches are primarily focused on the safety of the long-term facility occupants or users, no examples will be given that specifically focus only on them. Most building codes already provide considerable assurance of safety for these facility occupants. The short-term or more temporary facility users/occupants (construction workers and demolition crews) and those often less visible or apparent (maintenance personnel) are often ignored in design considerations. Examples will be developed for each of these groups of individuals.

Where applicable, the mutual benefit of design decisions to more than one select group of users or occupants will be pointed out.

ADDRESSING CONSTRUCTION SAFETY THROUGH DESIGN

In recent years, considerable attention has been focused on ways to address construction worker safety through design decisions. For designers to effectively address construction worker safety in the design phase, they must consider the various phases of construction. This is a departure from the traditional design approach as designers have traditionally considered only the safety aspects of a facility as it pertains to the end user. To effectively address construction safety issues means that the designer must consciously assess the implications on safety of each phase of construction as the facility is being built.

The role that designers can play in ensuring construction worker safety has evolved considerably in the past decade. In the United States, designers on a voluntary basis have assumed this role. The impetus for this change has been driven primarily by some large consumers of construction services. These are owners of projects that have sizable construction budgets and that have come to the realization that any worker injuries are ultimately incorporated in the costs of construction. These costs may be included inadvertently in the costs reimbursed to the construction contractors or they may be paid out directly by the firms to the injured parties as through liability settlements.

Another agent of change for designers addressing construction worker safety has been the tremendous growth that the design-build contract delivery system has enjoyed in the past five years. On design-build projects, it is a natural procedure for designers to address construction worker safety, as these are employees of both the designer and the constructor. While this has always been a feature of design-build procedures, the number of projects built with the design-build approach has increased at a phenomenal rate in the past few years. Design-build is capturing a significant portion of the construction market and will undoubtedly exert a strong influence in the future.

In Europe, designers are also beginning to address construction worker safety, but the motivation is somewhat different. There are now mandates for designers to assess the safety and health of the projects that they design. While they may not eliminate all hazards, they will reduce the dangers for construction workers to some degree. If hazards are not reduced or eliminated, they must still inform the constructors about these hazards.

Perhaps time will tell if the voluntary approach is as effective as one that is mandated. The mandates in Europe are certainly much broader in that all projects are addressed by the regulations. In the United States, the voluntary efforts are confined largely to industrial and process plant construction and to those projects where design-build is employed. Thus, the voluntary efforts are not widely employed on residential construction projects or on civil works.

When addressing construction worker safety in the design phase the designer must recognize and appreciate the dynamic nature of construction projects. When this is done, the designer can begin to address the safety concerns. There are many ways that the designer can incorporate safety into the design. In some instances, the designer might want to make determinations that actually dictate the construction procedure to be followed. For example, the designer might stipulate how the contractor is to safely work around overhead power lines. This might be done by dictating where access to the project is to be established, where cranes can or cannot be situated, or other procedures that will assist in minimizing the chance of making contact with the electric lines.

In steel structures, designers have begun to address safety in a variety of ways. In some cases, the designers encourage prefabricating steel assemblies on the ground and then hoisting them into place for final attachment to the structure. This has improved safety performance, but this also results in greater productivity and a higher level of quality. Because of these obvious and measurable benefits, this approach has become a standard procedure for several firms. The steel structures can also be designed so that the construction guardrails will be an integral component of the steel frame itself, thereby ensuring a higher degree of safety. Steel assemblies might also be so designed that the contractor will be tempted to install the permanent stairways early in the construction process so that safety and productivity are enhanced. Note that the designer need not dictate that the stairs be installed first, as the contractors will readily recognize the benefits of the early use of the permanent stairways. Even the steel connections can be designed to encourage safer construction procedures.

In the finishing portion of the project the designer should be mindful of any hazardous materials that are being incorporated in the fabric of the completed structure. Some adhesives emit toxic fumes during the curing process. Hazardous emissions might also result from some types of insulation, different paints, treated wood, and a host of other materials that may be incorporated into a facility. While these emissions may be minimal after a "degassing" period has elapsed, some threat to safety also exists for the permanent occupants of the facility. Since the construction workers are at greater risk, the designer should be careful to disclose any such hazards that are known to exist or that have a potential of existing.

ADDRESSING MAINTENANCE PERSONNEL SAFETY THROUGH DESIGN

There are two types of long-term occupants of most facilities. The first is the most recognizable as these are the occupants for whom the facility was originally intended. The second type of occupants consists of those who are charged with maintaining the facility. The safety of these maintenance workers are often overlooked and given little consideration, but they are long-term occupants and their safety is well worth ensuring through judicious design.

Some owners with sizable annual construction budgets (perhaps averaging hundreds of millions of US dollars per year) have recognized that the safety of the maintenance personnel is well worth preserving. Through the years they have found a variety of ways that facility designs can promote or ensure the safety of maintenance personnel.

Since they have sizable budgets for construction, they have documented these "best practices" and incorporated them in to their standard design details. For example, some firms have facilities that require the use of large vessels that have smooth domes above them. These domes may be ideal geometric shapes for the confinement of many substances, but they present readily apparent hazards to workers who must perform maintenance work on the domes. To address this hazard, some design manuals call for a permanent ladder to the top of the dome and a "ring" to be welded onto the center of the top of the dome. Workers can then attach lanyards to the ring and perform their elevated work in relative safety.

Maintenance workers do not currently have a strong lobby group to lead the effort to encourage designers to address their safety and health needs. Fortunately, it has been discovered that many designing for safety suggestions that make improvements in construction safety also improve the safety of the facility for maintenance workers. Thus, maintenance workers benefit, in many instances, from the same decisions that made the facility safer for the construction workers.

ADDRESSING DEMOLITION CREW SAFETY THROUGH DESIGN

Designers historically envision only the long-term occupancy period of the facilities they design, with perhaps no consideration given to the ultimate destruction or demolition of the facility. In some countries, structures are utilized for centuries with no apparent end envisioned for the useful life of the facility. However, some structures in the United States are expected to have a useful of life of perhaps only a few decades. The design of all structures, especially those with relatively short lives, should seriously address the means to be used to dismantle them.

With a greater attention to sustainability in design, it is also incumbent for the designer to consider how the facility components will be able to be utilized in subsequent facilities. It is this issue of sustainability that changes the design parameters to be considered when taking safety into consideration during the demolition phase. Note that if sustainability is to be ignored, the facility might be imploded or perhaps completely demolished with large machinery with minimal risk to demolition crews. It is with the strong emphasis on sustainability in reusing and recycling materials that the dismantling of facilities will require closer attention to the safety of the demolition crews.

When a facility is deconstructed with the intent of reusing and recycling many of the materials, the method of facility destruction is grossly altered from the traditional means that have been employed. Ideally, a facility that is to engender sustainability will be able to have many of its structural components removed intact. Just as the facility was constructed by adding one piece after another, the deconstruction of the facility should permit a similar dismantling of the facility. This would suggest that the deconstruction sequence is essentially a reversal of the process with which the facility was initially constructed. To design a facility that can be “unzipped” will require considerable thought and ingenuity. To ensure the safety of the workers who perform this work adds another dimension of concern for the designer. Fortunately, as will be pointed out, a facility that is designed to be dismantled with maximum reuse of the facility components will generally automatically improve the safety aspects for the deconstruction workers.

Perhaps the primary area where the safety of demolition can be addressed is in the structural domain. This can be explained by means of several examples. Note that the assumption is that the materials that are removed are expected to have a maximum potential for reuse. If this assumption were to be ignored, it would simply be safest to "level" facilities by some mechanical means, e.g., heavy equipment or explosives. If materials are to be reused, with a minimum of rework and reprocessing, direct manual intervention in the deconstruction effort will be required. It is under these circumstances that worker safety is to be assured.

The structure is the facility component that designers should consider first where safety during demolition is to be addressed. For example, in a wood frame structure, several decisions can be made as to the details of how the structural components will fit together. Many of these will have implications on safety during demolition. The primary concern is related to the degree of certainty related to the outcome associated with the removal of any connector. For example, with wood frames, the connections might be made with nails, wood screws, carriage bolts, or similar connectors. For these options, the carriage bolts are the only connectors that require a predrilled hole. From a sustainable perspective, the carriage bolt would result in the least damage to the wood member when the carriage bolt is removed. There would potentially be considerable damage to the wood with a nailed connection, and slightly less damage (than with nails) with the use of wood screws. Note that from a safety perspective, the carriage bolt would also be the preferred type of connection. In the deconstruction process, the worker potentially has greater control over the removal of the carriage bolts and should know the implications of removing one at a joint. Worker training could be effective in helping workers to have a greater understanding of the structural system and the proper means by which it should be dismantled. With the removal of nails and wood screws, the worker would have less certainty in predicting when a structure will collapse. There may be several nails or several wood screws at a connection, but the worker has less assurance of knowing how many can be removed before the structure is on the verge of collapse.

If the structure is made of steel columns and beams, a similar analysis will result. In general terms, the connections can be welded or bolted. With welded connections, the deconstruction effort will be more destructive at the joints as these will be dismantled with cutting torches and possibly saws. If the connections are bolted, the demolition effort will essentially consist of removing the bolts. Again, the removal of bolts will give quite predictable results with welded connections offering greater uncertainty about the timing of connection separation. With the steel connections it is then apparent that the sustainable approach and the safe design approach would favor bolted connections. Naturally, the designers must evaluate the unique circumstances for each structure before making the final decisions about the connection details.

Concrete structures fall into the two broad categories of precast and cast-in-place. While there are variations of these, these form the two basic groups. Cast-in-place concrete is essentially a monolithic structure that requires considerable effort to deconstruct. Precast concrete structures offer some opportunity for reuse of intact members, an occurrence that is rare with cast-in-place concrete. From a safety perspective, the precast structure generally permits the demolition team to have greater control over the dismantling of the structure. Thus, the deconstruction of precast structures is generally safer, especially where reuse and recycling of intact members is to be achieved.

CONCLUSIONS

Designers have accepted as fact that they play a crucial role in formulating the degree of safety afforded for facility users. It is a relatively new concept for designers to recognize that they must also address the safety needs of construction workers, maintenance workers, and deconstruction workers. While U.S. designers readily embrace addressing construction safety when they are part of a design-build team, this has not become a universally accepted responsibility. Some owners who are large users of construction services in the U.S. have begun to mandate that the designers of their facilities must address the safety and health needs of construction workers. These trends are voluntary and not as broad or sweeping as the mandate currently existing in Europe. Thus, concern about designing for safety is expanding in the U.S. on a voluntary basis while in Europe it is fueled by compulsory requirements. Owners have a requirement to have safe facilities (whether constructing, using, maintaining, or demolishing) and this requirement might very well be imposed by them on the designers they hire.

Perhaps the greatest obstacle to addressing the safety of construction workers, maintenance workers, or deconstruction workers is the lack of knowledge on the part of designers to ensuring their safety through design. As ideas are generated on ways to improve the safety for the "other" facility occupants, designers will feel more comfortable in addressing this need.

It is suggested that research be conducted to identify and verify the best practices related to designing for the life cycle safety of facilities. As information is acquired on the successes that designers have had in addressing life cycle safety through their design decisions, this knowledge must be disseminated in the design community. This will enhance and accelerate the learning process for the entire design profession and ultimately enhance the safety of facilities in all phases of their existence.

BUILDING ACCESS AND USABILITY
– A MANAGER'S GUIDE

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ABSTRACT

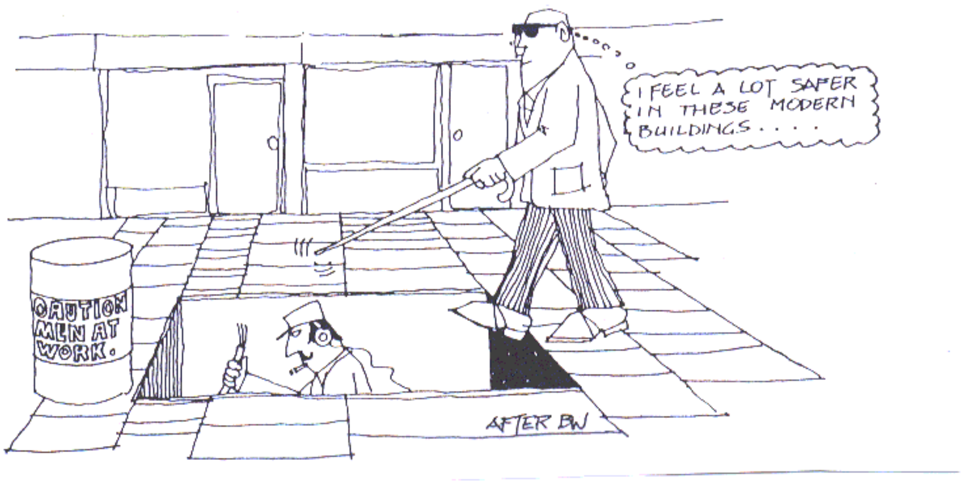
This paper is about the provision of guidance material about building access and usability for use by business managers in major public organisations. The guide may be used or adapted to help designers and managers assess the accessibility and useability of buildings in preparation as well as to assist the effective operation of buildings in use.

In addition, it may be used to assist:

- Briefing architects and building contractors
- Auditing drawings submitted for building consent
- Job supervision during project management
- Evaluation of contract performance pre- and post occupancy

The paper explains the benefits of providing universally useable and accessible work environments. It describes how the guide assists managers with the practical every day implementation and operation of the requirements of accessibility legislation. The concept of the 'accessible route' is used to describe compliance requirements. An illustrated accessibility checklist is then provided to enable managers to check regularly compliance of the buildings they supervise and use with good practice. The paper describes how the guide was prepared, its content, its use in practice and its potential for adaptability and re-use.

Keywords: Building Accessibility; Checklist; Guidance; Facilities Management



INTRODUCTION

Much of the work in facilities management of the VUW Centre for Building Performance Research (CBPR) has focussed on development of a generic participatory building evaluation process for negotiating the ongoing quality of building facilities (Kernohan et al, 1992). The process allows both building users and providers access to decision-making processes that can affect the design, operation and management of facilities. The method has been used for a variety of purposes, from helping select buildings for organisations, to assisting briefing processes, to finetuning recent occupancies, to troubleshooting in buildings that have difficulties adapting to change.

A major issue is - what to do with the knowledge gained from evaluation activity? Outcomes typically generate two types of response:

- They require immediate corrective or further investigation action
- They can be used to feed forward information for future action

The latter response implies the need to generate knowledge databases derived from information gained from building evaluations. The development of such databases is not a straightforward matter (Kernohan et al, 1992, p130-134). Apart from implementing corrective or investigation action, a principal outcome of CBPR building evaluation activity has therefore been not the development of databases but of guidance and checklists to describe the relationships of people, organisations and buildings (Baird et al, 1996). This has led to the development of building appraisal systems such as 'Building Quality Assessment (BQA)' distributed in Australia, New Zealand (NZ), the UK and the US (Baird et al, 1996, p53-58 and 74-76). More modest and more focussed guidance material for specific client organisations has also been developed.

This paper describes the development of one example of the latter type of guidance material. It describes development and use of a business manager's guide to building access and useability requirements in a major New Zealand national public organisation. While the guide and its preparation is for a specific New Zealand situation, the principles underlying the preparation of the guide and the legislation referred to itself is relevant to many other building and management situations and to the legal requirements of other countries.

THE COMMISSION

The CBPR was commissioned by the NZ Department of Social Welfare (DSW) (now Work and Income New Zealand [WINZ]) to prepare a guide to help their office managers ensure that the buildings they use provide a good, useable work environment for all their employees including people with disabilities. As access requirements are written for use primarily by designers and building control officials, office managers are usually unaware of ways in which they can help to ensure good compliance is achieved. The commission provided a unique opportunity to present requirements for building access and useability from an office management perspective. The guide was produced by a consensus process. This involved discussions and evaluation activity with office and building management and human resources staff of the client department. Consultant expertise on building access and useability came from the CBPR. This included use of the records of building evaluation activities.

Managers' Responsibilities

Health and Safety legislation in New Zealand places responsibility for health and safety in the workplace on employer and employee alike. The employer is charged with providing a safe workplace. In implementing employers obligations in large organisations, office managers assume devolved responsibility to ensure safe work practices are enacted and a safe workplace provided. Some office managers have little knowledge of what is involved or experience of addressing issues of accessibility, usability, health or safety. To meet the needs of staff and visitors with respect to building accessibility, DSW office managers needed means to ensure that general and specific procedures could be put in place to meet their responsibilities for health and safety. Guidance material was required for office managers that would:

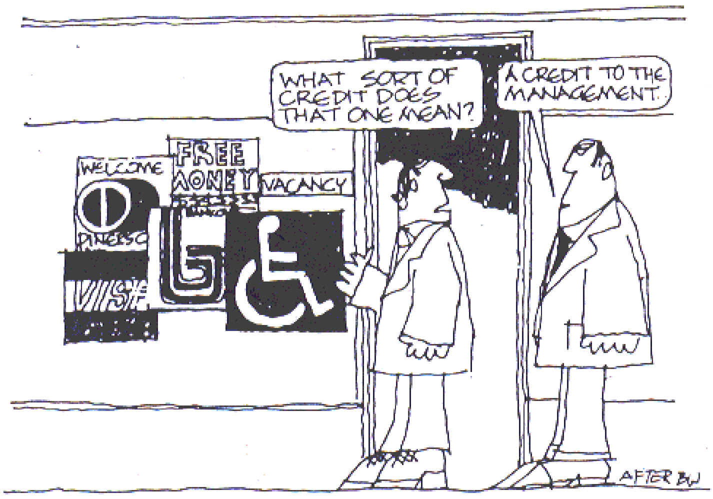
- be informative, clear, concise and easy to use
- require them to take specific action on a regular basis
- require them to seek advice from building users as well as from experts such as facilities managers.

The developed guidance material therefore requires office managers to:

1. **check** regularly, e.g. monthly that the building is accessible. A checklist has been developed in the guide to ensure relevant checks are made. The check can be informal by inspection but covers simple items such as ensuring that :
    - "accessible" car parking is properly policed and signage is maintained
    - ramps and entrances are kept clear of goods and bicycles
    - cartons, recycling bins, photocopying machines or other office equipment do not obstruct corridor and doorway clearances
    - "accessible" toilets are not locked and do not have cleaning gear stored in them
    - tension on door closers is not too heavy
    - signs for "accessible" toilets and listening systems are maintained on main entrance noticeboards, on lift lobby information boards and on room entrance doors
    - lighting is well maintained - particularly on stairs
2. **audit** all new buildings and any building alteration, which requires a building consent, for compliance with mandatory accessibility requirements.
3. **review and monitor compliance** with the access requirements for any change of use.
4. **avoid the common errors.** These are identified from the research as including failure to provide:
    - designated and signed "accessible" car parking spaces
    - ramping and paving with complying gradients, landings and handrails
    - a 300mm minimum wall-door clearance when door opens back into an enclosed corridor
    - adequate numbers of "accessible" toilets with complying lobby clearances, layout and fittings
    - reception desks with lower work surface and adequate depth under
    - listening systems with any permanently installed public address system
    - adequate, appropriate signage (access and hearing symbols)
5. **identify any special services and facilities**. This is necessary to cover any new staff member with a disability and any existing staff member who develops a disabling condition.

BUILDING USEABILITY – WHY ACCESS IS IMPORTANT

Useability is important because it is a fundamental requirement and a basic purpose of building design and construction. Buildings are used for living and social activities with the unstated assumption that people can physically enter and use them. However, people involved with the movement of goods (buyers, delivery services and maintenance personnel) into, out of and within buildings, young children, parents with pushchairs and people with disabilities will all experience various levels of exclusion from independent physical access to and use of buildings because of the way particular elements of buildings are designed.



Since the NZ Accident Compensation Corporation (ACC) began collecting injury data in 1974, there has been a consistent pattern of between 35% and 40% of all compensation pay out being caused by slipping, tripping, stumbling and over-reaching. About another 18% of total pay out is caused by factors such as: something giving way underfoot, misjudgment of support, loss of hold, loss of balance and collisions (Kernohan and Wrightson, 1992). These causes can be related to activities that occurred in and around buildings in about 17% to 22% of the total compensation paid. However, these percentages could be significantly affected by the 20% of total pay out, which is not adequately described in the data summaries. A conservative estimate of the cost of compensation pay out by ACC for injury by the above causes in and around buildings is $400 Million. Compared with this, the collective cost for injury in and around buildings resulting from fire, earthquake, electrical wiring, hazardous substances, poor air or poor lighting is less than 2% of the total compensation pay out.

Access requirements for people with disabilities, because they focus specifically on the design and detailing of ground and floor surfaces, of gradients, heights and the ergonomics of fittings can be considered as a primary means of addressing the major causes of injury in and around buildings. When usability requirements, most notably the access requirements for people with disabilities, are implemented in accordance with their mandated priority in building design they result in buildings which are more efficient, safer, more convenient for **everyone** to use and offer the potential to significantly reduce injury and health costs. The bottom line for **universal usability** is the accessibility requirements for people with disabilities.

A Useful Rule
A useful rule for determining the types of disability and the degree of incapacity that have to be accommodated when defining the design detail necessary to provide access for people with disabilities was established by John Bails (1983). Called the 80 percent rule it is based on satisfying the needs of 80 percent of each of the following three groups so that they can achieve independent access to buildings available for public use:

- the most able visually impaired people from age 18 to 60,
- other ambulant people with disabilities from age 18 to 60 years and,
- wheelchair users in the age range 60 to 81 years.

In New Zealand in 1994, 40% of the population defined themselves as having some disability or long-term illness. 26% of the population either cannot run, or have difficulty running 50 metres, walking 800 metres or walking up a set of stairs. 14% of the population have sensory and neurological disabilities. Comparable statistics apply in other countries. With most of these people with disabilities now participating fully in the working, training and recreational aspects of community life and with an aging population that is going to need more flexible work environments for a longer working life, usability and accessibility of buildings is of increasing importance.

THE ACCESSIBLE ROUTE

Provision of access is one of the six principles and purposes of the *NZ Building Act 1991*. These principles are shared in many countries. Any building work on a new public building or alteration to an existing public building, for which a building consent is required, shall provide "reasonable and adequate" access to enable people with disabilities to enter as a worker or visitor and carry out the normal processes and activities.

Access requirements are implemented in practice by means of the "accessible route". *NZ Standard 4121:1985* follows the walk-through sequence of the "accessible route" in the logical order of priority in which compliance details must be implemented for designing approachability, accessibility and usability into the built environment. This ensures that anomalies, like an accessible principal entrance with no access from car parking or street boundary or an accessible toilet inside a building with a non-complying principal entrance, are avoided.

The "accessible route" is defined in the *NZ Building Code* as:

"an access route useable by people with disabilities. It shall be a continuous route that can be negotiated unaided by a wheelchair user. The route shall extend from street boundary or carparking area to those spaces within the building required to be accessible to enable people with disabilities to carry out normal activities and processes within the building".

The "accessible route" applies to all parts of a building and its environs except for such places as plant rooms and pumping station shafts.

Key elements of the "accessible route" are that:

- it is continuous
- it enables "unaided", or independent, access so that a person with a disability can approach, enter and use a building without requiring assistance
- it must link both car parking and street boundary to the "accessible" entrance(s) so that the building remains accessible from the street boundary when the "accessible" car parks are in use.

THE CHECKLIST

The Checklist was produced as part of the guidance material to assist office managers and building facilities managers to achieve compliance with mandatory access requirements. It is also used as a means of quality assurance measurement for evaluating the performance of both buildings in preparation and buildings in use. The checklist is not a substitute for the requirements of formal access legislation. However, it does provide a simple guided procedure to ensure office managers, and others including designers and facilities managers, can undertake their responsibilities with regard to the health and safety of employees. Clearly, such procedures and guidance are applicable beyond a public service context and that of New Zealand legislation. The principles of accessibility advocated in the guide are as generalisable and universal as should be accessibility itself.

The Checklist is set out, first, as a summary. The summary page identifies thirteen areas of compliance (sections) to be rated by inspection by the office manager as part of the regular monthly check. The sections of the Checklist follow the same priority sequence established in NZ Standard 4121:1985. They are: Carparks; Footpaths and Ramps; Kerb Ramp; Stairs; Corridors, doors and doorways; Toilet facilities; Showers; Public reception counters and desks; Surface finishes; Controls; Visibility factors; Places of assembly; Signs. Each section heading and box provided seeks an overall assessment for that section based on the levels of compliance for its individual items.

Each section is given an overall rating of:

?	**"good"**	*provision greater than minimum compliance requirement*
?	**"OK"**	*provision equal to minimum compliance requirement*
?	**"poor"**	*provision less than minimum compliance requirement*
?	**"nil"**	*no attempt to provide*
?	**"NA"**	*requirement not applicable (eg building has no lift or stairs)*

Figure 1 below illustrates the nature and level of content of one of the eight pages of the Checklist. The guidance material also provides reference for those managers who wish to learn more of the detail of means of compliance or of the theory behind the mandatory requirements. Failure to achieve a rating of "good" or "OK" requires the office manager to take action. The guide provides advice on the type and range of action that may be appropriate in different circumstances.

ACCESSIBILITY CHECKLIST

FOR DSW MANAGERS AND BUILDING MANAGERS

Building Name ______________________________

Site/Address ______________________________

Year built/last altered ______________ No. of floors (including ground floor) ______________

Total gross floor area (sq. m) of upper floors (only if building has 1 or 2 upper floors) ______________

No. of carparks servicing building ______________ Checklist application date ______________

Check each section of items, and circle the numeral or dot for any individual item that has **less than required provision**, then enter in the box provided an overall assessment for that whole section as:

GOOD	- provision greater than minimum compliance requirement
OK	- provision equal to minimum compliance requirement
POOR	- provision less than minimum compliance requirement
NIL	- no attempt to provide
NA	- requirement not applicable (eg building has no lift or stairs)

ACCESSIBLE ROUTE
(Enter this assessment last, after checking all other sections)

i identifiable accessible route
- from street boundary and carparking, to and throughout building
- no projections or window or door swings obstruct assessible route

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CARPARKS
"Accessible" carparks are required in the following proportion :
- 1 for up to 10 parks provided
- 2 for up to 100 parks provided
- 1 more for every additional 50, or part thereof provided

i provision of required proportion of "accessible" car parks servicing building
ii "accessible" carparks are identified by "access symbol" (on ground or post)
iii have a level, paved surface 3000mm minimum width
iv located as close as possible to building entrance

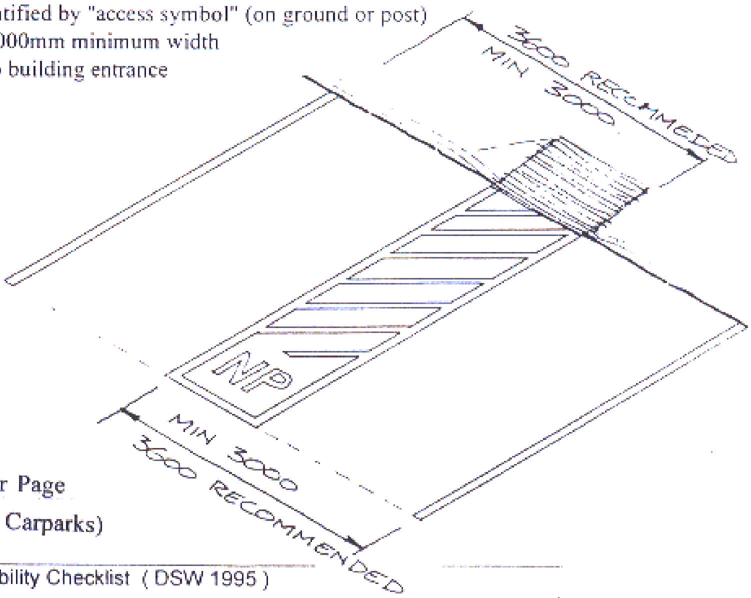

Figure 2 Checklist - Cover Page
(Accessible Route; Carparks)

Building Access & Usability - Accessibility Checklist (DSW 1995)

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Figure 1: Sample page from accessibility checklist

CONCLUDING COMMENT

This paper has illustrated how guidance material can be developed directly, from information gathered from processes of building evaluation, to address specific aspects of building use. The paper has demonstrated that such uses of the outcomes of building evaluations can be modest and straightforward yet of significance. The guide was distributed nationwide throughout the offices of DSW with the endorsement of the Director-General. It remains an official document of the newly formed WINZ. Over 250 office managers are charged with the responsibilities addressed by the guidance. Feedback, although anecdotal, indicates that the document is well received and well used, and that its use has effected good practice with respect to building accessibility and useability.

In addition, the paper shows how facilities managers and others concerned with the human resource aspects of building use might develop their own processes and guidance material. Such material assists building users and their managers to collaborate in building operation systems that enhance the working environment both physically and in terms of an effective, efficient, safe and comfortable working environment. Such processes and the guidance material resulting are an outcome of recognising that good facilities management requires dialogue between building providers and users and that building quality in the design, operation and management of building facilities is a matter for ongoing negotiation and the application of dynamic processes which allow such negotiation to operate both openly and effectively.

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SAFETY IN BUILDING MAINTENANCE DESIGN

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ABSTRACT

Within a planning process, buildings maintenance and its safety implementations need particular care since they are the very beginning of planning operations. Maintenance works often cause different accidents due to various conditions. It is therefore important that maintenance performance and safety at work imply the recognition of risks and the detection of suitable technical solutions aiming at accident prevention.

We must define the range of risks linked to this side of planning, which is often misunderstood, in order to achieve an effective prevention as far as safety at work is concerned even through a careful production of papers relating to maintenance operations.

Keywords: Executive design, maintenance, quality, safety.

PLANNING WITHIN THE BUILDING PROCESS

Recently the success of the technological culture has improved materials and the technological content and has increased the complexity of organisational structures which have to realise it. Then there has often been an important relationship between production and plan; this has caused high-tech solutions' success. On the other hand this has caused a higher exposure to risks coming from unusual works, asking for an improvement of prevention measures.

In traditional works, it is the plan that shows the inability to cope with complexity for planning works that can remain as time goes by. In this case we could pay little attention to safety implementation with serious accidents at work.

Planning work does not stop with the construction of the building because the management phase has to aim at building maintenance.

For those buildings built in the last 40 years, we have found through their management that performance and quality of planning choices is generally very low. The supposed duration of new materials and innovative technological solutions has often shown itself to be the main cause for blight condition.

We must not underestimate the phenomenon of "corrections within works", which modify initial planning choices. This phenomenon has marked not only common buildings, but even buildings designed by famous designers. A clear example is what has recently happened with the plan for the new Auditorium in Rome: Wrens Piano

Building Workshop s.r.l. and the pool of firms led by Gepco started quarrelling from the very beginning because the latter has complained about deficiencies in the plan.

Recently Mr. Piano assessed that some amendments had to be carried out during works and linked to the construction site schedule.

Functional needs, work requirements and specifications have to be detected from the beginning of the planning phase. In the working plan they must include technical performance and esthetical contents. This is the basic presupposition to achieve total quality of construction work.

SAFETY AND PLANNING PROCESS

Quality and safety have become two inseparable elements in planning process. During the last CIB W99 convention held in Milan we have noted that the lack of safety requirements in the plan has caused many serious accidents and damages to the health of workers on construction sites.

As we have already said, operational modifications during construction cannot be accepted any more if we aim to achieve good quality.

It is up to those in charge of the construction process planning phases to get from the beginning the management of safety aspects through a responsible and thought-out plan.

The new role of the "planning phase co-ordinator" has to support the designer through the building conception and/or programming phases in order to have safety requirements satisfied. These requirements have to be identified in specific solutions aiming at working phases planning in terms of workers' safety and health. By detailing general works and possible special works we have to insert, together with their costs, safety criteria to implement in each operation. In doing so, we can effectively prevent accidents and industrial diseases. It is then advisable to perform many quality controls during working, checking safety implementations adopted on the construction site.

Controls frequency must not be limited to the operational phase, but it has to occur even in the planning process. Figure 1 shows the need to identify the steps of an in progress co-ordination in plan activity (under Italian law).

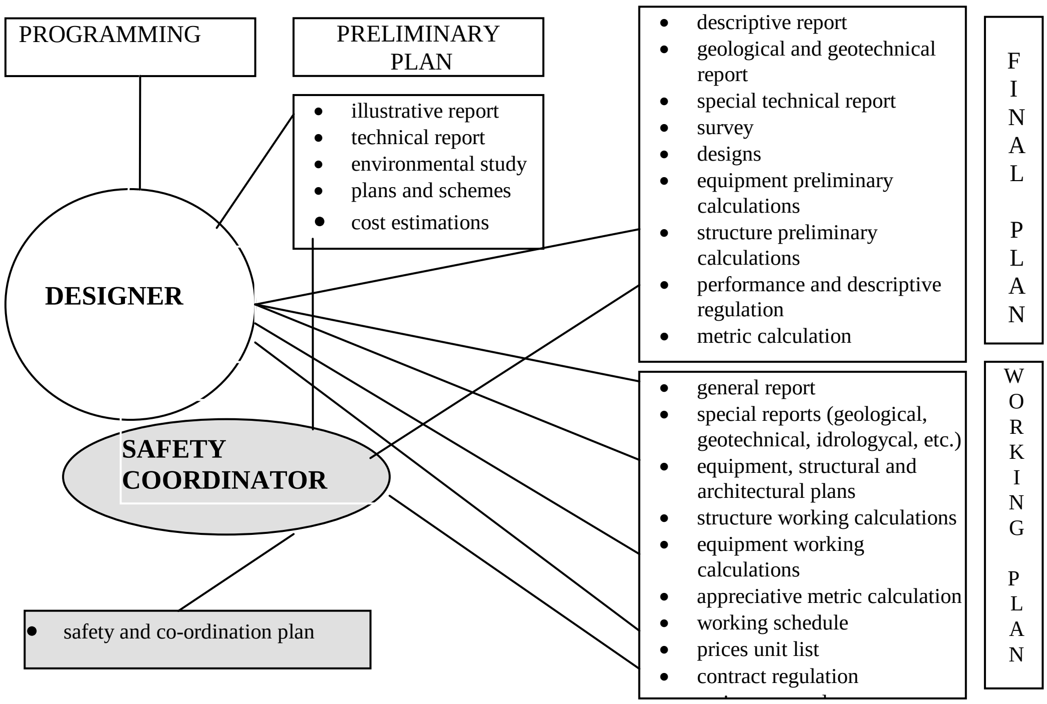

Figure 1 Design planning co-ordination

MAINTENANCE SEEN AS SAFETY IN FUTURE WORKS

Safety in works that will be carried out in the future has to be stressed right from the planning phase. Materials, technical or equipment systems choices cannot forget the need to keep, as far as possible, high levels of performance, quality features, efficiency and economic value.

The aim to preserve performance quality over time is part of the plan itself and it needs all implementations for its achievement. Maintenance planning is part of the working planning process and reliability, longevity and maintenance requirements have always to be present when we draw up norms and choose construction methods.

In Italy a working maintenance plan is now compulsory under law. It is the basis for future works to be carried out in safety. Since it is an extra document linked to the working plan, it must foresee plan and programme maintenance works in order to retain time performance, quality features, efficiency and economic value.

Even if it can have different contents, according to intervention features, it is usually made up from some operational elements: operations handbook (related to technological equipment in order to avoid early degradation), maintenance handbook and maintenance programme.

We believe that maintenance aspects cannot be limited to drawing simple or complex handbooks and in scheduling different steps: we think that they must be defined during the planning phase in order to get all possible solutions for any kind of risks.

The chance to exploit architectonic simulation software, in which we can check our building works in its entirety, allows us to act on planning level by identifying possible risks and to find solutions to solve them.

Looking at future works, there is a planning instrument that can co-operate with risk identification. This is the Building Maintenance Safety File, written by the safety co-ordinator. It aims at conceiving all operational situations and maintenance works coming out from planning solutions through two kinds of designs:

- Plans concerning paths, entrances, manoeuvre areas and managing areas;
- Structural and graphic plans where all necessary elements are detailed concerning worker's safety and health.
- Works and Maintenance Handbook, Information Programme and Building Maintenance Safety File, arranged in the working plan. These must be open to possible variations and corrective action during building site construction or where works are in progress. These have to be inserted in the graphic plans that the site engineer or safety co-ordinator have to issue at the end of work.

Figure 2 shows the specific contributions of the designer and the site engineer to define the building maintenance design.

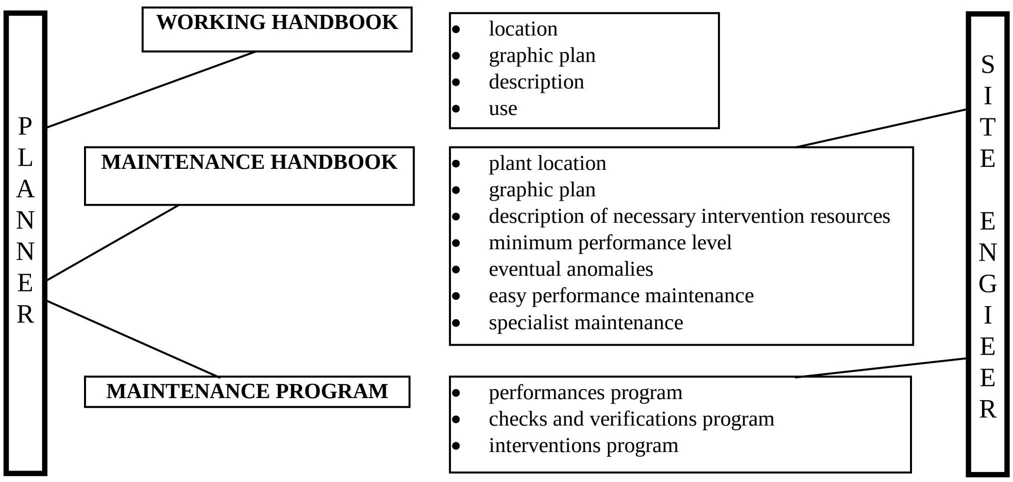

Figure 2 Designer and site engineer contribution to building maintenance design

The planning-phase and the execution-phase coordinators define and bring up to date planning process through the compilation of BMSF (Figure 3)

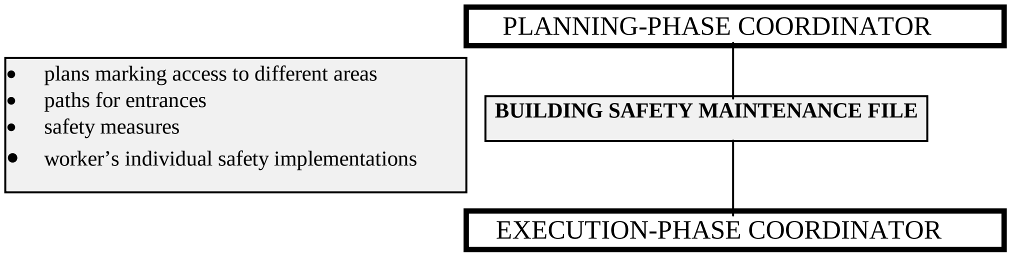

Figure 3 Role of the Building Safety Maintenance File

The goal of keeping quality standards over time requires successive verifications and amendments that have to consider blight situations, obsolescence, degradation provisions and risks caused by special works.

In File check cards we must record eventual risks coming from ordinary and extraordinary maintenance, then implementations aimed at neutralising those risks and finally, all safety equipment compulsory for the construction works. The presence of hoists for access to maintain facades, the provision of safe stairs to reach roofs, atria or other technological horizontal passages, the provision of canopies and vaults protection structures, the presence of scaffold anchors are all important elements in a plan having to consider future maintenance. We have also to insert all necessary equipment for future works even if these are not among the possible work issues. It is also true for those cases in which the condition to guarantee efficiency and safety results in the necessity of the maintenance programme.

The planner must therefore foresee a wide range of risk cases led by a sound and updated knowledge of building and plant engineering structures that is feasible in plan drawing through an interactive comparison between different technical solutions and the charts describing potential risks.

CONCLUSIONS

As we could see within the planning process, maintenance planning develops from the conception phase playing an important role in stressing safety aspects and building quality. The designer and the other technicians have to co-operate to produce technical documents that will facilitate quality management over the life-time of the building. Risks, solutions and safety equipment identification need the awareness that we work inside complex buildings. This is seen as integration between structural elements and plant-engineering equipment.

Safety process is not limited to complex operations on the construction site but concerns a more difficult field - that is the building itself. A building that during its life cycle must undergo some verifications and integration in order to guarantee performance quality as the plan requires.

FINDING THE RIGHT LEGISLATIVE FRAMEWORK FOR GUIDING DESIGNERS ON THEIR HEALTH AND SAFETY RESPONSIBILITIES

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ABSTRACT

The paper rehearses a number of key reasons why obtaining good health and safety performance in the construction industry is a complex and difficult task. It is only since the advent of the Temporary and Mobile Construction Sites Directive of 1992 that legislative duties have been formally imposed on designers and planners. The detailed nature of this law in crucial in encouraging the most appropriate response from designers.

The Irish and United Kingdom legislation derived from the Directive is compared and contrasted, and recommendations are made for changes to the Directive and the UK Construction (Design and Management) Regulations.

Keywords: Designers; construction; health and safety; legislation

Background

The management of health and safety in the construction industry wherever it might take place in the world is never easy or straightforward (Whittington *et al* 1992) and requires leadership and good project management (Anderson 1999). The accident record is never going to be as low as, for example, certain manufacturing or the service industries, but there are clear moral, ethical and economic arguments that all involved in both the visualising of construction projects and the realisation of them to exercise what effort they can to reduce risks to workers, members of the public and to the built and natural environment.

Part of the "problem" is that the industry is, by its nature, particularly complex. For example there is a -

- Diverse client base, with, at one extreme. some clients spending vast sums of money each and every year on construction work, and at the other extreme 'one-off' clients commissioning work perhaps once every 10 years of so;
- Diverse end-products - the single house to the Millennium Dome;
- Diverse working environments - 'green fields', 'brown fields', in and underwater, underground and even in space;
- Diverse procurement methods. The simple exchange of providing a sum of money in return for specified good and services has been overtaken by the considerable complexity of procurement contracts which may or may not mention health and safety issues;
- Diversity in processes, activities and materials;

- Diversity of people and skills. Engineering on its own has never been enough to guarantee success, but these days the skills of, for example, project managers, accountants, materials technologists, lawyers, behavioural specialists etc need to be part of the action;
- Diversity of external and internal pressures within organisations. Commercial pressures, including consulting engineers grappling with fee competition or contractors having to wrestle with increased competitive tendering pressures, add to the general stress levels of industry that have to be managed; and
- Differing sizes of organisations. It has been stated (Health and Safety Executive 1998) that in the UK in 1996/97 there were 1,599,300 workers in the construction industry of which 785,000 were self-employed, and it is estimated that of the 200,000 contractors in construction, only 12,000 employ more than 7 people.

Society, looking on from the side-lines has taken the view, generations ago, that exposing persons engaged on construction work to excessive danger while at work was unacceptable. In the past, the crude but understandable driving force for detailed legislation came from the examination of the accident record within the industry concerned.

The main thrust of the law was to -

- provide physical safety measures at the point where the danger was greatest - the evidence being gleaned from the accident record; and
- to lay the duty to provide these measures on the employers of the persons at risk.

There the law rested for a number of years, but a fundamental legislative review (in the UK in 1974) (Robens 1972) found this approach both defective and incomplete in that there were, in fact, more parties that could contribute to the positive improvement to the safety and health of the working environment, and the time was come to extend the legislative duty of care.

From 1974 the UK legislation remains focused on the duties and responsibilities of employers for ensuring the health, safety and welfare of their employees but other parties were drawn into the safety equation including designers, manufacturers and suppliers of plant and equipment.

CONSTRUCTION SITES DIRECTIVE OF 1992

The net really began to widen (and quite rightly too) with the advent of the Temporary or Mobile Construction Sites Directive of 1992. Again the researchers for the legislators went forth to find what was wrong or missing. Two matters came to their attention, and found their way into the preamble to the Directive. Each is worth examining in turn, the first being -

"Whereas unsatisfactory architectural and/or organisational options or poor planning of the works at the project preparation stage have played a role in more than half of the occupational accident occurring on construction sites in the Community".

This whole clause is about shortcomings during the pre-construction phase. Rightly, the spotlight was being shifted (at least in part) to what happens in the various activities and procurement processes before action commences on site. Nor are the shortcomings during this period trivial - they apparently contribute to over half of all the accidents. Three 'shortcomings' are specifically mentioned -

1. unsatisfactory architectural options;
2. unsatisfactory organisational options; (a bit unclear perhaps); and
3. poor pre-construction phase planning.

Notice "design" or "designer" is not mentioned, although one could well argue that "planning" could hardly not involve some sort of work that could be termed "design". The second preamble to note is -

"Whereas when a project is being carried out, a large number of occupational accidents may be caused by inadequate co-ordination. particularly where various undertakings work simultaneously or in succession at the same temporary or mobile construction site. It is therefore necessary to improve co-ordination between the various parties concerned at the project preparation stage and also when he work is being carried out".

The message is that proper co-ordination of different peoples' work activities actually on construction sites will reduce accidents, and that this co-ordination needs to start at the beginning of the pre-construction phase of any project.

The Articles of the 1992 Directive
In the effort to improve health and safety, Article 2 defines three parties - the client ; the 'project supervisor' (acting on behalf of the client); and the 'co-ordinator for safety and health matters' appointed by the client or the project supervisor for certain specified duties. There is no actual mention of the appointment of the project supervisor, but the definition of 'project supervisor' is important to realise who this person/organisation might actually be. The definition reads -

"Project supervisor means any natural or legal person responsible for the design and/or execution and/or supervision of the execution of a project, acting on behalf of a client"

Clearly this person can have a remit beyond health and safety issues. Article 9 places duties on 'employers', (but 'employers' are not defined in Article 2) and the duties on employers are only mentioned in the context of work "on the construction site". It seems appropriate to deduce that in the context of this Directive 'employers' actually means those companies or organisations employing workers on site during the construction stage.

The wording of Articles 3, 4, and 7 clearly imply that the client and the project supervisor have similar if not identical duties, and Article 3 requires the client/project supervisor to ensure a health and safety plan is prepared before construction work starts.

Article 4 contains the crux of the matter when it requires that when architectural technical and organisational aspects of the project are being decided in order to plan the various items or stages which are to take place simultaneously or in succession, the client/project supervisor shall take account of the risk hierarchy contained in the 1989 Framework Directive.

Articles 5 and 6 contains the duties of the safety and health co-ordinator.

The net result is that the client can undertake some of the pre-construction health and safety work himself and need not appoint a project supervisor. He has no option but to appoint safety and health co-ordinators. An alternative approach is that he can delegate his duties to a project supervisor to act on his behalf, but that person has to have the brief of responsibility for the design and/or the execution (i.e. the construction work) and/or the supervisor of the construction work. The all important duties under Article 4 about safety in the detail of design and planning stages are those of the client or, if he chooses to delegate, the project supervisor.

COMPARISONS

Some recent research into health and safety co-ordination within the construction sector in 15 countries is of interest (Comite international pour la prevention des risques professionnels du batiment et des traveaux publics 1999) especially where it reveals differences in approaches to the implementation of the 1992 Directive.

The following comments are offered in a comparison between the approaches of the Irish and the UK governments in translating the Temporary or Mobile Construction Sites Directive into national law.

The minimalist Irish version

The Irish Regulations bringing the 1992 Directive into Irish law came into force on 6 June 1995 as part of the Safety, Health and Welfare at Work (Construction) Regulations 1995. "Design" is defined as -

"....the preparation of drawings, particulars, specifications, calculations, bills of quantities in so far as they contain specifications or other expressions of purpose according to which a project, or any part of a project, is to be executed"
This definition would certainly include what is commonly known as 'temporary works'.

The definition of "project supervisor" -

"means a competent person appointed under Regulation 3(1) and responsible for carrying out the appropriate duties specified in these Regulations"
and Regulation 3(1) states -
"It shall be the duty of the client to appoint, in respect of every project, a project supervisor for the design stage....." and Reg 3(3)(a) continues -
"nothing shall prevent the client appointing himself or herself as project supervisor if competent to undertake the duties involved". This directly parallels the Directive.

There is reference (Reg 4(3) to the possibility of the appointment by the project supervisor (not the client) of "a competent person as health and safety co-ordinator", but the duties of the project supervisor for the 'design stage' are expressed as follows -

(Reg 4) "*Duties of Project Supervisor appointed for the Design Stage:*
It shall be the duty of the project supervisor appointed for the design stage to take account during the design of a project ....the general principles of prevention as specified in the First Schedule of the Principal Regulation, and of any safety and health plan or safety file... and to co-ordinate in these respects the activities of other persons engaged in work to the design of the project." Thus the project supervisor (design) has to use the risk hierarchy and undertake the co-ordinating duties over all others engaged in design. He has apparently no powers to give directions to designers (but see the text of Reg 5 below).

Although 'designer' is not specified, Regulation 5 is headed "Duties of Designers" and states -
"In any case in which a person is engaged in work related to the design of a project..... it shall be the duty of that person to take account of the general principals of prevention as specified on the First Schedule of the Principal Regulations....and to cooperage with the project supervisor to enable the project supervisor to comply with these Regulations and take into account any directions from the project supervisor appointed for the design stage.

So both planning supervisors and designers have to "take account" (the words used in Article 4) of the risk hierarchy during the design and planning of the project. This is what their work will be measured against. The Framework Directive risk hierarchy contained in Schedule 1 of the Irish Safety, Health and Welfare at Work (General Application) Regulations 1993 is virtually the same as Schedule 1 in the UK Management of Health and Safety at Work Regulations 1999. Interestingly, the Irish regulation 6(2)(e) requires the project supervisor (construction) to take responsibility for not only co-ordinating the health and safety arrangements, but also for "the implementation of safe working procedures".

The more elaborate UK version
The UK Construction (Design and Management) Regulations 1994 came into force on 31 March 1995 and contained the main provisions of the 1992 Directive.

Both 'design' and 'designers' are defined, and the Directive specification of the 'project supervisor' has been split into two - the "planning supervisor" and the "principal contractor" both of which have to be examined by the client for 'competence' and the 'allocation of adequate resources for health and safety'. There is no reference to the appointment of separate 'safety and health co-ordinators' as mentioned in the Directive. There is an associated extensive "Approved Code of Practice" with the Regulations.

In the pre-construction phase, the duties of both the planning supervisor and the designers are of interest. In terms of wording, the more important of these texts is the one that relates to the duties on designers. This is at Regulation 13.

"Every designer shall ensure any design he prepares...includes adequate regard to the need to avoid foreseeable risks to the health and safety of any person...."

There is no direct reference within this Regulation to the 1989 risk hierarchy. In respect of risks, the Approved Code of Practice states that (para 59 and 60) -

"An integral part of the design function ...is the need for the designer to carry out a risk assessment (and)..... the designer needs to examine methods by which the structure might be built and analyse the hazards and risks associated with these methods in the context of his design choices"

GETTING THE LEGISLATION 'RIGHT'

Writing about any sort of 'ideal' framework for health and safety legislation on designers is always going to be a matter of personal opinion. The author offers the criticisms below from a background of employment experience in the industry and from involvement in the creation and amendment of health and safety legislation. The author's more recent international consultancy work and PhD level research work has brought an appreciation of the legislation of some other countries. Internationally, the legal duties on designers may be different (or non-existent) but construction industry accidents and cases of ill health remain depressingly identical in any country.

The 1992 Directive

This Directive got it nearly right in that it involved the parties to the pre-construction phase in health and safety duties and responsibilities. However the role and function of the 'project supervisor' is not clear enough, and the idea of having 'co-ordinators for safety and health' can take responsibility away from the people that matter - the professional planners and designers. What would be more direct and provide additional clarity would be to -

- put the duties on the client for health and safety at the pre-construction stage and leave them there;
- not allow the client to offload these responsibilities to other parties;
- broadly define the other parties to the pre-construction phase as those producing plans, specifications, calculations etc and require them to act in accordance with the risk hierarchy so as to enable the client to comply with his health and safety obligations;
- require the client, with the help of those other parties to the pre-construction stage, to produce a document at the tender stage for the construction work giving all the necessary project-specific information on health and safety and the residual risks that the contractor will have to manage;
- delete reference to any project supervisors and separate co-ordinators; and
- add a bit more detail to the 'general principles' in Article 4 .

Irish 1995 Regulations

These Regs appear to allow the Client to duck out of a great deal of what should, in the author's view, be their responsibility for directly managing the health and safety issues. They are creating, funding, procuring, investigating and defining the details of the project, and if the strong message came from them that health and safety was a high priority, then those working for them (which is, in effect, everybody) then things would happen. Their Reg 3 only requires the client to (a) appoint the project supervisor - which could easily be divorced from the actual design team, and (b) keep the health and safety file.

Requiring designers to "take account" of the risk hierarchy is exactly right in principle, but lacks the necessary detail in guiding designers and planners as to what they should actually do to satisfy compliance with the legal phrase "take account".

The UK CDM Regs

The CDM Regs are not right in certain details (Consultancy Company 1997, Anderson 1998, Court 1998 and Thompson 2000) - in particular, the tortuous phase in the designers duties (Reg 13(a)) to -

".....include among the design considerations adequate regard to the need to avoid foreseeable risks...."

which dilutes the Directive and should be scrapped. The mini-summary of the risk hierarchy in Reg 13(2)(a) - (i), (ii) and (iii) should be deleted, and designers should be required to ensure that their planning and design processes comply with the detailed risk hierarchy presently contained in Schedule 1 of the 1999 UK Management Regs.

The CDM Regs should include the Directive requirement for co-ordination of health and safety issues in the pre-construction stage but that it should be exercised *on behalf of the client* (who should retain full responsibility for health and safety matters until the construction work actually begins) by the lead designers appointed by the client. The UK invention of "Planning supervisors" as separate legal persons should be axed, as should be the requirement for competence and resources - neither of which latter requirements are in the Directive. The best people to judge, control, influence and direct the management of health and safety issues during the pre-construction design phases are the designers themselves, supporting the client in meeting his health and safety duties and responsibilities. Engaging other organisations or people outwith the design team seems destined to add paperwork, communication problems, extra costs and create possible confusion of responsibility.

With new clarity into the actual Regulations, the Approved Code of Practice should be abandoned - it further "muddies" the legal waters. It should be replaced with practical hands-on guidance documents for all parties to the pre-construction process. This should primarily be in the form of case-study examples. The producer of the documents does not matter. What does matter, given the culture of compartmentalisation of the industry, is their clarity, quality, scope and relevance to those who need the advice. The EU guidance on the 1992 Directive (Commission of the European Communities 1993) provides a good strategic framework on which to build.

CONCLUSION

Ensuring a safe place of work "at the sharp end" in our complex and diverse industry is indeed not an easy or simple task. There are many problems and "barriers" to complete success (Anderson 1999), but what can be done in the key pre-construction stage is, as yet, an under-developed region with substantial potential. Designers and planners are responsible professional people and deserve clarity both about what they are expected to achieve, and guidance about how they might go about it. Having done that, the best thing enforcement bodies can do is to let them get on with the job while seeking out and publishing from time to time examples of particularly good practice.

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CDM AND DESIGN: WHERE ARE WE NOW AND WHERE SHOULD WE GO? – A PERSONAL VIEW

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ABSTRACT

This paper sets out the author's personal views on the effectiveness of CDM designer duty implementation. It suggests that while some excellent implementation of both the spirit and letter of CDM design principles has been seen, the overall response has been more patchy. UK designers' compliance with legal planning constraints is probably more reliable and the forces that bring this about could usefully be considered in developing the regulatory framework that surrounds CDM compliance.

CDM AND DESIGNERS: WHAT DOES THE LAW REQUIRE?

The key requirement for designers in CDM is regulation 13. There are links between designers and other duty holders in other regulations but the crux of the matter is in regulation 13. CDM Regulation 13 does not set out specifications that buildings should meet. It seeks to influence the design product its requirements are in respect of the design process and the conclusions reached may differ depending on the risks.

CDM requires that designers think about their designs as they are designing. They must think about them and their potential implications on construction health and safety in a certain way. Designers should be able to demonstrate that their design decisions reflect ideas to reduce risks at source, or if that is not feasible design in collective safety measures rather than individual ones

For instance the risk of falls from height might be reduced or designed out altogether by arranging for plant rooms to be installed in basements rather than on the roof.

A collective safety measure providing protection to all eg edge protection at the roof edge is always better than providing harness attachment points for use by individuals working on the same roof. The same process can legitimately produce different conclusions. It may not be possible to put the plant room in the basement because car parking is needed there. If so the plant room probably has to go on the roof. The designer must consider how it can be put there safely. He may for instance design modular systems that can be lifted to the roof top rather than constructing the plant room on the roof in situ. This would vastly reduce the need for potentially dangerous work at height.

The real point is that if asked designers should be able to talk about and justify their designs with respect to the implications on construction health and safety.

WHAT IMPACT HAS CDM HAD ON THE WORK OF DESIGNERS?

The response of designers to CDM has been variable; sometimes excellent, sometimes negative almost to the point of hostile contempt, but more usually something between these two extremes.

The high performers

There are undoubtedly some design organisations where CDM is or has become an organic part of the design process. When challenged these organisations and the people working in them can explain with confidence how the design outcomes incorporate and reflect CDM principles. They have the confidence to make health and safety judgements and to defend them. The people involved can react appropriately, without the need for total reliance on paper systems. Paper (or computer) records are important to them, but as means of recording and organising design decisions rather than making them.

In the author’s experience, this is most commonly encountered in organisations where the underlying principles of health and safety management in CDM were embedded before the regulations appeared. It is therefore uncertain whether these successes represent the impact of CDM or pre-existing good standards.

Success is often found where designers and constructors already work together more closely eg design and build, or construction management companies. In such organisations procedures and disciplines for closer cooperation between designer and construction manager already existed. Such interchange between designer and constructor on ‘buildability’ inevitably creates a greater likelihood that the CDM design principles will be implemented.

CDM success also tends to be found in larger and more complex projects. If you are building something so complex as an oil refinery it is essential that all the different parties, including designers speak to each other – simply in order to enable the complicated site to function at all. The potential costs of failure mean that the client will insist on high standards of coordination and usually monitor to make sure they are applied. Realistically the need for such co-ordination and attention to detail rarely seems so urgent for the construction of a pair of detached houses.

CDM design processes also tend to be more apparent where what is being constructed is itself a safety critical item. This is often the case in engineering construction where items such as pressure vessels must be constructed to the most exacting quality standards. The levels of assurance needed leave no room for doubt. Designers are forced into thinking about every variable that could affect the integrity of the finished item. While this is no guarantee of CDM compliance, it certainly makes it more likely that construction health and safety issues will emerge and be dealt with at the design stage.

The poor or non performers

There is a core (albeit increasingly isolated) of designers who resolutely fail to accept that they have a locus in the generation of acceptable safety standards on site. They see their role as exclusively producing a detailed specification of what should be built.

Their view is that whatever the problems are in realising the design, they are solely the construction contractor's problem. They focus on the product of design and see the design process as the exclusive preserve of designers into which other players may not enter.

Some examples encountered by the author follow

> The initial presence of highly fragile liner sheets, prior to final placing of the 'non fragile' top sheet presents a major hazard to roof workers. If liner and top sheets are specified to be the same size the presence of unprotected liner sheets can be kept to the absolute minimum as the work progresses.
>
> The significance of the hazard and this simple precautionary principle was pointed out at a national designers' conference on roofing. The response from the floor was entirely negative.
>
> "This is all very interesting, but I really don't think there's anything you health and safety people can tell us. After all we have been designing roofs for many years and everything we need to know is already in the Building Regulations".

This attitude reflects a complete misunderstanding of CDM design principles. In particular there is no recognition of the distinction between design process (the CDM focus) and design product (the Building Regulations focus).

> An accident occurred where partly cured blockwork fell from a roof edge onto a worker. Investigation revealed that the blocks formed a parapet wall at the roof edge. The blocks were to have been laid on the top flange of a horizontal beam. The specification was for blocks that were wider than the flange. When the blocks were laid they unavoidably overhung the flange edge. Consequently as the mortar cured the blockwork started to tilt until it eventually fell

The interesting point is that this potential problem had been identified by the site management beforehand. They had brought it to the designer's attention, but the response had been that this was a design issue and therefore not their concern. Their job was merely to ensure that the structure was built as specified. This is an extreme, and thankfully rare example of wilful refusal by a designer to consider the risks arising from his decisions Nonetheless it is symptomatic of the difficulty some designers have in recognising the extent of their decisions' impact on other people at work.

The middle of the road performers

In the UK there are very few designers who have not heard of CDM or are unaware that it requires them to do something about construction health and safety. In this respect CDM has been a huge success. There is no possibility of turning the awareness clock back and that is a fundamental CDM success.

Most designers have taken action in response to CDM, but we are still some way from it becoming as integral a part of the design process as for instance costing or aesthetics. In the author's experience the shortcomings can usually be categorised as follows

Lots of paperwork or real decisions?
When CDM was introduced many designers were uncertain what it required. Because they are not confident about how to demonstrate compliance, some take the precautionary option and include every piece of information they can think of in their CDM information package. As a result we might (and often do) see a designer's CDM' package containing

- All design drawings, preliminary and final;
- Copies of all correspondence between designers and other project partners;
- Extensive copies of HSE guidance (whether relevant to the project or not);
- Copies of contract agreements.

This is a huge volume of data, but it often contains no indication of how the design decisions have dealt with anticipated construction risks or where the safety critical issues are. Even if such information is contained in the package it is difficult for others to isolate it from the mass of surrounding data.

The more complex and high risk a project is the more likely it is that extensive information will required for effective CDM compliance. Even so the key point remains that the information should be necessary, relevant and useful to those who will subsequently be planning and carrying out the construction work.

An emphasis on administrative process
There are distinct advantages in incorporating CDM design procedures into wider organisational procurement procedures. This can make CDM design processes an organic and automatic part of procedure. However if this is to succeed it is important that the arrangements really do provoke and prompt explicit CDM design processes.

The author has encountered situations where the CDM title is included on the face of the procurement design procedures, but has little or no practical influence on the generation of CDM design thinking. For example an organisation's existing procedures may have included specific elements concerning the checking of compliance with planning constraints. CDM may have been highlighted as an additional element to check at that stage, but in reality the skills necessary for it to be carried out have not been developed and consequently it does not happen. At the same time a CDM reference in the procedure nourishes a false sense of security that CDM is being properly addressed

Such shortcomings are indicative of a situation where CDM disciplines are perceived as a mere administrative function rather than part of the professional competence of designers.

Identifying the problem or making a decision?
The first step in designers' satisfaction of CDM duties is to identify the hazards that could arise in building their designs and the risks that they might present. The second step is to make a decision on whether or how the design can be adapted to deal with the risks.

While many designers have developed awareness of construction site hazards and an understanding of how to evaluate the attendant risks, it is often the case that this is not developed into design decisions to counteract them. This frequently occurs where CDM is seen as an addition to design processes rather than an integral part of it. Thus the design may be completed and then the construction risk is addressed. The risks can often be easily identified, but because the design has already been completed it is difficult to change it if necessary at this later stage. This emphasises the key CDM principle that successful compliance is always easier and more likely when health and safety issues are considered right from the earliest design stages. It is always more expensive and difficult to resolve them at a later stage.

The CDM 'ghetto'
CDM is often seen as an additional item to conventional design processes (a 'bolt on extra'). As above it may be that this results in CDM being considered at a different time to other design activities. Alternatively it may result in CDM being dealt with by a stand-alone group separate from the rest of the design team. In both cases potential outcomes are that;

> CDM will be considered at a later stage when it will often be too late to have any beneficial effect; and
>
> An adversarial culture can develop where CDM is seen by some as an obstacle to completing the overall design, rather than an integral part of it.

HOW CAN IMPROVEMENT BE GENERATED?

CDM is a legal requirement placed on designers. So is compliance with planning constraints and the Building Regulations. Designers' awareness of and compliance with the latter is more widespread and reliable than with CDM. Why is this so?

To a significant extent this must reflect the fact that CDM is a much more recent innovation. Planning constraints are an innate part of the design community's 'culture'. Ensuring compliance with them is as routine a part of design business as making sure its tax affairs are in order. Realistically recognition of CDM is not at this stage of 'cultural' maturity.

Awareness of CDM is not the only distinction. As previously stated there are few designers who do not already know that CDM exists. But knowledge of a CDM requirement is different from a cultural response to it. Organisations' cultures are provoked by external influences as much as generated inside them. In the event of non compliance with planning controls and the Building regulations the risks are well known. There is a real likelihood that failure will be detected because;

- There is a widespread and sophisticated enforcement infrastructure designed to monitor it;
- Proposals are automatically subject to regulatory scrutiny; and
- They are open to public examination as well.

Furthermore failure can be costly because:

- Planning wrangles can lead to major project dislocation
- Changing designs at a later stage is expensive; and
- In the last resort demolition of non-compliant buildings can be financially lethal

How does the enforcement environment surrounding CDM compare?

Between 1995 and 1997 there were apparently 6 prosecutions of designers under the CDM regulations. Of these

  - 4 followed serious accidents where design features played a significant role
  - 1 concerned failure to notify a client of their CDM duties
  - 1 concerned failure to provide adequate information with the design

It must be recognised that prosecution is but one part of the Health and Safety Executive's regulatory function. Improvement and prohibition notices are a key part of the enforcement profile and the impact of more routine investigation and inspection (although difficult to quantify) is crucial. Nonetheless, the message perceived by designers is that the real likelihood of getting 'caught' for CDM failure is low. In light of the relative regulatory profiles, it will not be surprising if satisfying the planning official is seen as a higher priority than satisfying the HSE one.

It may well be that the CDM enforcement rate has increased more recently, but if it has it does not seem to have resulted in any significantly increased perception amongst designers that the likelihood of detection and/or sanction is higher.

In an ideal world we should not have to rely on the threat of enforcement to generate action. In reality it is a crucial element and this author believes that its profile needs to be raised if more consistent designer compliance with CDM is to be achieved.

Raising the enforcement profile does not necessarily equate with increasing its frequency. Instead key enforcement priorities can be clearly identified and once established robustly communicated and consistently pursued. For instance falls through fragile materials have already been mentioned as a major killer. Alternative materials are available and there is rarely good reason for designers to continue specifying fragile ones on new roofs instead. Designers should be clear that the latter is unacceptable and that they can expect action <u>will</u> be taken against them if they persist.

Similar initiatives could be appropriate for unnecessary specification of heavy building blocks, failure to consider construction phase stability in steel structures and others.

There is a danger that concentration on such specific items may cause some designers to focus on the design product rather than the design process. However, in the author's view, this is outweighed by the benefits of a more immediate designer realisation of their central role in generating safe working conditions.

The items suggested are not esoteric ones. They are ones which should easily come to light with a minimum of consideration by designers. As such, greater regulatory expectation of such solutions should surely be welcomed by those designers who are already committed to and positively working for CDM compliance.

OTHER PLAYERS

Having highlighted HSE's enforcement role it must be realised that in practice their resources are limited. They simply cannot be expected to solve CDM designer 'culture' problems themselves, either through their enforcement powers or other activities.

The following are suggested as key players.

Clients
The creation of client duties in respect of construction health and safety was the second major new development created in CDM. Clients inevitably set the whole 'tone' of a construction project including for health and safety. If clients apply pressure to reduce costs, to the point that health and safety standards suffer, it is hardly surprising if those they engage on the project team follow that lead. On the other hand if clients make it clear that they expect high standards it would be a foolish designer who fails to respond accordingly.

Practical actions clients could implement might include;

- In selection of designers, demanding to see evidence of how design was altered to take account of construction risks in previous work;

- Demanding to see how designers propose that risks to operators of the completed building have been addressed eg arrangements for window cleaning access or identification of safety critical elements for any future construction work on the completed building;

- Formal commitment to and execution of best practice standards in liaison with designers eg evidence of compliance with appropriate client 'benchmarking' standards under 'Movement for Innovation' initiatives.

Planning Authorities
Planning authorities could draw applicants' attention to CDM design requirements in routine application procedures. This would not be to substitute for HSE's enforcement/monitoring role, but would be a powerful way of raising the profile of CDM at early design stages.

Planning authorities could also usefully serve as vectors for HSE awareness raising initiatives. In particular the planning application route might be used to closely target explicit information on HSE enforcement initiatives to the design community. This would serve to raise both the overall and enforcement profile of CDM. (It is one thing for a designer to glance at a small article on HSE initiatives in a professional journal, but quite another for him to receive a message from HSE direct to his correspondence tray)

Such initiatives would be useful examples of ‘joined up government’ of direct practical relevance to business.

Training

Effective long term change of designer culture largely depends on the education and training of design professionals in CDM principles. In this it is important that CDM is not presented as a ‘stand alone’ extra. It should be training and education about designing for health and safety rather than about CDM. Defining and providing the infrastructure for such education and training is a challenge to be met by the design profession.

Clear definition of the competences required to attract designer professional qualifications should cement clarification of the standards designers need to meet to be competent. It is a fundamental requirement of occupational health and safety law that people carrying out work are competent to do so safely, both in respect of their own safety and their impact on others’. This extends to the competence of designers to fulfil CDM functions. Perhaps, if the necessary CDM competences are clarified, they could form the basis of a regulatory initiative aimed at ensuring individuals working in design organisations possess such skills.

VISIONS FOR THE FUTURE

How will we know in say 5 years time whether or not CDM has successfully and effectively embedded itself in the professional outlook of designers? The real test is what actually goes on in the mind of designers. I suggest some simple practical criteria as follows.

- **CDM SHOULD BE NORMAL**
  Considering CDM design issues should become as commonplace and routine as considering access for disabled persons.

- **DESIGNERS SHOULD BE INFORMED**
  A well used copy of core HSE guidance on construction health and safety should be found by every designer’s desk.

- **CONFIDENCE ABOUT CDM**
  A designer should always be able to confidently say something positive when asked to describe his or her CDM conclusions for the project in hand.

SAFETY PLANNING AND DESIGN STAGES: PUBLIC WORKS PROCUREMENT ROUTES IN ITALY

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ABSTRACT

In Italy, the recently enforced Public Works Act (Law 109/1994 modified by Law 216/1995 and Law 415/1998) requires project managers of public clients to act as clients' representatives as far as health and safety matters are concerned. Consequently, project managers and project sponsors who have to choose suitable public procurement routes and to manage the awarding phase, could take into account, according to the features of the building to be constructed, the whole range of safety-related pros and cons built in each procurement route. They should also assess the amount of human resource to be spent in constructing such a building when scheduling public works as early as possible. Moreover, executive PPMs have to report to the local government and to the technical chief executive officers of the public administration. Indeed, the public client organisation has to comply with detailed and burdening rules whilst such different agents (political and administrative bodies) could be described as decision-makers acting within an adversarial climate.

So, planning and scheduling options and design solutions (sometimes awarded and transferred to private practitioners) could be affected by conflicts occurring between the different parties belonging to the client organisations, engendering counterproductive results from the safety and health viewpoint.

This paper demonstrates that a ISO 9000:2000 quality-managed technical bureau of the public administration (overall when Local Authorities are considered) should co-ordinate health and safety planning during the design phase in the most effective way. Quality Management Systems are forcing public managers and clerks to devise written procedures to be closely followed in order to define actions, responsibilities, precedences, and tools. Therefore, project managers and designers working on the behalf of the public awarding organisations could easily perform their tasks if there are no misunderstandings or uncertainties about skills and duties when writing health and safety plans.

Keywords: Quality management systems, safety planning, public administration

PUBLIC CLIENT ORGANISATIONS AND QUALITY MANAGEMENT

This paper deals with the logical sequence of actions necessary for the application and certification of a quality management system complying to UNI EN ISO 9001:2000 standard when applied to technical areas of local authorities (particularly in city halls) when health and safety planning has to be performed.

In Italy, in fact, there are city halls (Cornate d'Adda), public companies (ALER Lecco) and regions (Region of Lombardy) certified to ISO 9001 standards. On this occasion, the quality management system is considered to cover only the technical area, while in some cases the entire municipal administration (of which the technical area is obviously a subsection) is subjected to the same system. The introduction of the quality management system is used, therefore, to reengineer the operational models of the technical bodies inside the local authorities. In this matter it is useful to remember that the law outline regarding public works has clearly placed importance on the review and management intent of the technical offices of contracting administrations.

The municipal technical area is an organisation located within the municipal structure to which certain tasks defined by municipal statute are assigned. Particularly interesting is the case of the technical areas in municipalities with less than 10,000 inhabitants since their number in Italy is considerable and because they, by technical and dimensional characteristics, are comparable with average Italian professional practices. On the other hand, small municipalities require specific proposals, in order to facilitate the effects of the reform intent which, therefore, must not only be exercised in medium-sized or large administrations: think of the difficulty in finding qualified employees to fill the position of public project manager (PPM).

It is through the statute and regulations of the bureaucratic organisation of offices and services that the organisation and operation of the technical area is determined. Knowledge of the reform of public works in the private sense is fundamental in analysing the operation of the technical area which introduces the concept of the territorial Local Authority as subject of distribution of services and managerial function. The cited normative sources have each taken steps in their sector to distribute the prescribed tasks amongst the subjects which within the administration will need to be in charge of their execution: for example, defining the figure of PPM, clerk of works, safety supervisor during planning and execution phases. For example, this deals with the procedural route of typical contract bidding, acting on those parameters that remain dependent on internal conduct rules within each administration. It is possible, therefore, to increase efficiency (duration of the entire contract) and effectiveness (optimum selection of competitors and the identification of the substantial contents of the offer to be favoured), strictly remaining within the normative restrictions.

The client assumes different characteristics for the public works service. The client may be the local authority which orders the service; the citizen or the company that requests to be able to execute one of its powers; the professional who, on behalf of their public or private client, comes to interact with technical employees; or the institution in whose name the employee carries out the supervision activity.

In the municipal technical area we can observe that:

- particular purchaser requirements do not exist, but, in fact, mixed competition between internal structures and external bodies is triggered for the responsibilities of planning, job management, etc. Often when a municipal technical area is well-managed, it is able to distribute services on behalf of other associated or health administrations;
- the eventual legal obligations would make the situation grow even worse;

- the city hall council could maintain, within a *public management* strategy, that it is opportune (for the purposes of improving consent through the sharpening of services distributed to the citizen) to obtain quality management system certification for the technical structure as well;
- the business process reengineering, beyond being functional in introducing a management control system, could cause an improved business environment given that each person is acknowledged their own responsibilities and authority.

At this point, the need to define a course, that is to say a methodology, arises for the municipal Technical Area to approach the form and substance of the quality management system. The main difficulties are:

- the possible incompatibility with the procedures set by law and the requirements of a specific element of the quality management system;
- the impropriety in considering the municipal technostructure as an independent unit which is not inserted into other offices or bodies of city hall itself.

Once the cited operations have been carried out, special, unique methods and instruments must be configured, keeping in mind two primary and logical transfers:

- the transfer of the "manufacturing" system of UNI EN ISO 9001 regulations, even with the help of other complementary normative documents;
- adapting the fundamental "high business management" concept to the Technical Area Manager.

Regarding the degree of function externalisation, we can confirm that qualification of subcontractors will be advisable (including, therefore, professional practices) through the canonical criteria by now consolidated, up to the tendency to require them to show quality management system certification. In this way, in addition to demanding qualitative aspects from the contracting companies, we require them, on behalf of the technostructure, from the consultants.

PUBLIC PROJECT MANAGEMENT AND HEALTH& SAFETY PLANNING

In Italy, PPMs have to act as safety client’s representative, according to the Italian law 528/1999, which modifies the law 494/1996 that was enforcing the EC Directive about health and safety on construction sites. The above stated requirement entails that such clerks have to lead to a sort of trade off between different kind of stakeholders within public administrations: politicians, top managers, and designers during the briefing stage (the so called preliminary document preceding design phases).

First of all, the PPM has to identify the awarding procedural route concerning public works and, sometimes, design services (including safety supervision, too). The PPM must evaluate (through a written formal statement) inner available skills and resources before preferring outsourcing. On the other hand, PPMs are compelled by law to appoint simultaneously (as early as possible) designers and safety supervisors. Otherwise, as it is usually happening in Italy, safety supervisors are appointed after the completion of the detail design, vanishing without leaving trace. Furthermore, PPMs can choose amongst a deal of different ways for procuring design-related services:

1. keeping into the public technical office all design stages (outline, scheme and detail design phases);
2. awarding to private practices all design levels;
3. awarding to private practices the scheme and detail design phases;
4. awarding to building contractors the scheme and detail design phases;
5. awarding to building contractors only the detail design phase.

It depends on specific conditions to be taken into account: however, such a decision-making process could cause critical effects from the safety-oriented point of view, because of the various attitudes shown by private practitioners which will not be involved later, during Public Works bidding and awarding phases. When selecting mixed options (involving both public and private design teams) PPMs and safety supervisors have to pay attention to adversarial or, at least, confused interactions amongst specialists. In any case, PPMs have to act as supervisors and co-ordinators upon designers, safety co-ordinators and clerks of works.

If safety management during design stages is considered from the project planning point of view, PPMs are forced to make themselves responsible when the master plan has to be arranged with the client board (politicians and top managers). PPMs should settle anything requires to be stated, even if the client board seems to not wishful to accept lags and delays due to safety risk prevention reasons. Although the Italian law singles out the client profile with the top manager of the technical office who is able to sign contracts, politicians are always interfering with technical matters. Sometimes they do not agree with PPM's decisions because of the different goals and targets that clients are mirroring (for instance political deadlines and polls are urging and pressing them), in spite of quality, safety, time and cost of Public Works. Indeed, the whole duration of the scheduled works could affect safety-related design solutions and options, increasing risk levels.

The safety planning supervisor (the safety co-ordinator at the design phase) has to be supported by the PPM when reviewing, above all, scheme and detail drawings and technical specifications. Likewise, PPMs, as Client's Representatives, are to assess and review health and safety plans and building files provided by designers and supervisors. PPMs should avoid the client board's ways of thinking and wishes urge private practitioners (when appointed and charged as designers) to neglect the safety co-ordinator's suggestions and advice during design stage. Politicians try to deal directly with private practitioners, supplanting public functional managers and PPMs. Unfortunately, private designers become tremendously troubled, because they are not able to identify the executive decision maker: they fear to follow technical advice when such purposes seem to be modified by upper agents (politicians). Furthermore, Italian law concerning public works is hampering (apart from certain exemptions) building contractors to be involved in design decision-making processes. Obviously, in so doing PPMs are not able to manage effectively project schedules and detailed diagrams (bar charts, networks, space-time charts, etc.) which will be completed and modified later by the bidders.

When detail design documents are not including shop drawings, it is not possible to provide to PPMs and safety supervisors with adequate information about scheduling. Consequently, they are not able:

1. to analyse the overlaps (as far the time is concerned) shown in the bar charts;
2. to resort to the various kinds of relationships and lags in order to lead away the overlapping activities;
3. to resort to interfering, free, and total floats to lead away the overlapping activities;
4. to visualise in the linked bar chart or in the network some specific safety measures to be complied with;
5. to compare simultaneously the histograms concerning each type of the human resources (overcrowding index) and the non-human ones (interference index) in order to smooth and level the peaks identified;
6. to modify the critical path, increasing the duration of the works fixed by the contract.

Moreover, awarding criteria are often focusing only on the lowest bid, instead of other parameters. Design and Build-like procedural routes could, instead, make easier a collaborative approach between clients and contractors when safety-measures have to be built in design drawings and technical specifications.

Finally, quality management system procedures could allow PPMs to appoint public or private designers envisaging a set of constraints and to counteract certain clients' amateurish behaviour. Moreover, PPMs, when appointed by the functional senior managers, should prepare a quality plan, which describes the scope of the project, breakdown structures, tasks, ways of working, etc. Safety supervision tasks and duties have to be pointed out. The following list is providing the framework of such a document, highlighting main clauses to be complied with.

Part One	*Scope management*
Part Two	*Project management contract review*
Part Three	*Gestione della Documentazione della Qualità*
Part Four	*Briefing, safety and design management*
Part Five	*Procurement management*
Part Six	*On site safety and construction management*
Part Seven	*Building final testing management*
Part Eight	*Project management-related non conformity management*
Part Nine	*Project auditing and control*
Part Ten	*Corrective actions*
Part Eleven	*Training*
Part Twelve	*Claim, dispute and resolution management*

Quality planning and safety planning during design stages are sharing the same goals: according to a proactive approach: client organisations and clients' representatives are trying to foresee, visualise and simulate troubles that could happen on site. Quality plans are useful tools in order to analyse and to manage risks as far as time and cost are involved, whilst safety plans are dealing with hazards and accidents. Nonetheless, close links between quality and safety matters need an integrated attitude. Plans of works and schedules made available to clients during the design stages will be accomplished only if PPMs, designers and supervisors are using "what-if" simulation techniques in order to diminish risk levels and unwanted conditions.

ISO 9000:2000 AND LOCAL AUTHORITIES' TECHNICAL OFFICES

The model of UNI EN ISO 9001:1997 will be soon be modified by UNI EN ISO 9001:2000 Standard. Revision of the standard coincides, moreover, with the reviewing and simplification of the entire family of ISO standards (including the abolition of UNI EN ISO 9002 and 9003 standards for the purposes of certification).

The main features of the revision to standard regard:

- orientation to the satisfaction of customers (in our case the political body and citizens/users/voters);
- organisation more suitable to the service industry (in our case the distribution of public design and safety supervision services);
- the ability of circulation of management subsystems for quality, which systematically reconnect;
- the ability to complement the product and/or service regulations (in our case the realisation of Public Works, the authorisation for execution of the Private Works);
- the universality of the regulation corresponding to the specificity of the business case (in our case the public technical structure);
- the adaptability and suitability of certain clauses in the case of non-applicability;
- the use of the terms of supplier, organisation, client/customer instead of subcontractor, supplier, client/customer;
- turning to a managerial style which facilitates the validation of customer needs within the organisation;
- the reference to continued improvement and the dynamic evolution of the quality management system;
- the periodic update of the quality policy;
- the documented and measurable definition of the qualitative objectives of management consistent with the quality policy (in our case the management execution plan);
- the emphasising of the quality plan (in our case project organisation);
- the focusing on the importance of human resources with particular attention on assessment of qualification and on the planning of training (in our case the multiple-year program of technical area training and employment investments);
- the institution of the business computer system (in our case the computerisation of the public institution);
- the investment in instrumental resources suitable for the distribution of services;
- the management of the physical and psychological safety and well-being of workers;
- the transfer of the analysis of the offer and the review of the contract to the review of explicit needs, but most of all, the implicit needs of the client/customer;
- the definition of the legal and regulatory outline within which the distribution of the service takes place;
- the confidentiality of the information communicated by the client/customer;

- the carrying out of the service as well as the product, amongst the processes to be controlled;
- the decorum and ergonomics of the work environment;
- the extension of the activities of drawing up, transmission, filing, preservation of document supports relating to the distributed service;
- the centrality of the systems which survey the degree of client/customer satisfaction;
- the determination of a measurement system of the performance levels achieved by the quality system;
- the carrying out of the link between the process control system and the improvement plans of product or distribution of the service;
- the evolution of the use of technical statistics in the management of data processing for the improvement of the qualitative levels of the product or service;
- the emphasis given to the meaning of continued improvement.

Such normative model foresees a reduction of clauses from twenty to four. For simplicity, where the references to the original clause are present in several clauses, only the prevailing one was pointed out. The clauses are:

- Management responsibilities, including: *management responsibility*, *quality system*, *document control*, *quality records*;
- Resource management, including: *training*;
- Process management, including: *Contract review*, *purchasing*; *purchaser supplied product*, *identification and traceability*, *process control*, *inspection and testing*, *Control of non conforming product*, *handling, storage, packaging and delivery*, *servicing*;
- Measurement, analysis and improvement, including *inspection and testing*, *inspection and test status*, *corrective and preventive action*, *internal quality audits*, *statistical techniques*.

There are two hypotheses to be formed:

- the introduction of the quality management system is decided upon by the city hall council and board and accepted by the technical area;
- the introduction of the quality system is requested by the general director, the city hall secretary or the technical area director and accepted by the council and board.

CONCLUSIONS

The quality manager becomes, therefore, the mediator between those who have knowledge regarding quality and safety and those who have administrative experience.

The quality manager covers a delicate role since which must at the same time actively involve the components of the area and avoid receiving continuous requests and claims. From this point of view, the area manager assumes managerial capacities, receiving the resources from the political body in order to be able to fulfil the objectives established by it.

The majority of consultation begins from the configuration of the quality manual since it thoroughly lends itself as a brief orientation document in the march towards quality management.

What is important is that the superimposition between functions, activities and people is clarified since the procedure is not a set rule but rather only a logical sequence: health and safety planning procedures are self explaining if there is a strong sequence to be complied with.

Experience so far, in terms of safety and quality management at the public administration (including some city halls, some special companies, some local health companies), reveals in fact, that often the employees feel like they are not listened to and left to themselves. Whereas the directors in the more senior roles feel exaggerated responsibility in the administrative processes without having sufficient operational autonomy.

Quality management-related procedures could allow PPMs and functional managers belonging to public administrations to carry on during quality and safety planning.

THE ROLES OF CLIENT AND DESIGNER FOR CONSTRUCTION SAFETY DESIGN IN JAPAN

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ABSTRACT

In Japan, the traditional public procurement system has dominated for a half century. This system is responsible for hindering aspects of designing for construction safety and health management in Japan. It is confronted here, and challenged to revise the present system. This paper describes existing circumstances of consideration for construction safety and health during the design phase. The emphasis is on the roles of client and designer.

Keywords: Client, designer, engineering consultant, responsibility, safety and health management, Japan

INTRODUCTION

Cooperation among client, designer, prime contractor, subcontractor, material supplier, and workers is necessary in order to improve the safety performance of the construction industry. Nevertheless, the Industrial Safety and Health Law, throughout a series of amendments, has increasingly emphasized the responsibilities of only prime contractors. It is ordinary practice in Japan that the prime contractor is mainly obliged for all worker safety and health related liabilities. As a result, safety management in the Japanese construction industry is nearly all implemented by prime contractors.

It is essential for the future improvement of Japan's construction safety and health performance that the duties of all project participants are identified and adjusted. It is particularly important that the responsibilities and roles of client and designer should be clarified. In this paper the general situation of construction safety and health management and designer classification in Japan are introduced. After analyzing the awareness and behavior of client and designer on designing for construction safety approaches for reducing occupational risks are presented.

GENERAL SITUATION RELATED TO CONSTRUCTION SAFETY AND HEALTH MANAGEMENT IN JAPAN

Legal framework on construction safety and health management

- The Labor Standard Law (1947): A chapter in terms of industrial safety and health is included in this law.
- The Industrial Safety and Health Law (ISH Law, 1972): This law lays down the responsibilities of the participants for safety and health in all industries, and provides the legal authorities in construction safety and health management.
- The Worker's Accident Compensation Law (1947): According to this law, employers are legally obliged to carry the worker's compensation for all employees.
- Some other relevant laws and ordinances: The Pneumoconiosis Law (1960), the Ordinance on Industrial safety and Health (1947), etc..

Main systems of contract on construction safety and health management

A construction company has to assign appropriate persons for establishment of safety and health management system. Under the ISH Law, general safety and health supervisor, safety supervisor, health supervisor, safety and health supervisor, industrial physician, office safety and health supervisor, relief engineering supervisor and chief engineer might be in the management system. The detailed persons who have to be assigned are in accordance with the scale of company (the number of employees) and the types of work. Furthermore, when multiple contractors are working in the same site, in order to strengthen safety and health management overall safety and health controller, master safety and health supervisor and safety and health controller are stipulated based on the scale of site and types of work. Compared to subcontractors, the prime contractor usually has advantages in terms of technical and financing competence, consequently, it is highly responsible for safety and health management. Evidence of a tendency for responsibility to be laid on the prime contractor can be found from many judicial precedents in Japan over the past 50 years.

Statistics

The number of employees in the Japanese construction industry reached a record of 6.57 million in 1998, accounting for 10.2% of all industrial workers. Due to characteristics of the productive process, safety and health management in the construction industry is more difficult than other industries such as manufacturing or services. Through a series of measures against hazards, Japan has made remarkable progress on labor protection and improvement of working environment, in particular since the 1970s. Figure 1 shows the statistics in terms of fatal accidents from 1965 to 1998. The number of accidents has decreased sharply from 1974 (the year of enactment of the ISL Law is 1972); however, the trend slowed in the last decade. This indicates that limitations exist in the present safety and health management system. Furthermore, it is a common recognition that construction industry is still the most dangerous industry in Japan: fatal accidents in the construction industry occupy about 40% of Japan's total industrial fatalities.

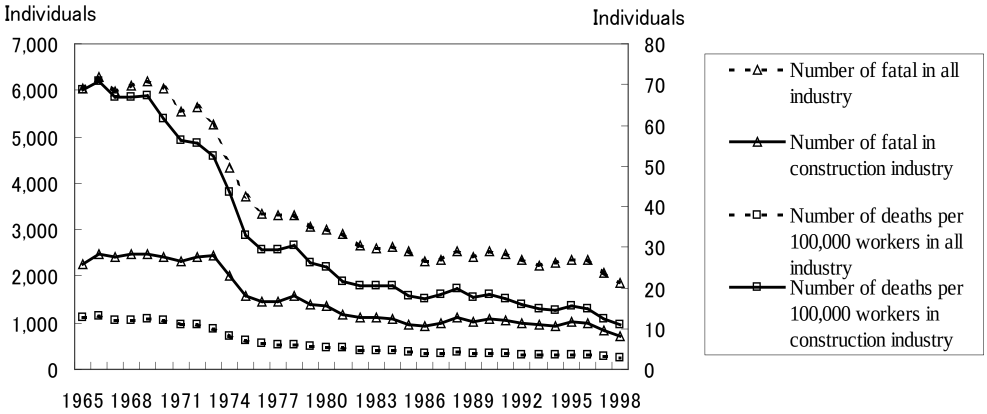

Figure 1 Number of fatal accidents and
number of annual deaths per 100,000 workers by year (1965-1998)

Figure 1 Fatal Accidents in Japan 1965-1998

Source: M. Kunishima & M. shoji 1995, http://www.kensaibou.or.jp/a01_1.htm and

DESIGNER CLASSIFICATION

There are mainly three kinds of designer in Japan.

- **“In-house” designers in client organization.**

Many Japanese public works clients have a large number of in-house technical experts such clients include central government (Ministry of Construction, Ministry of Transport, etc.) and its branch agencies, local governments (the prefectures plus Tokyo, Hokkaido, Osaka, Kyoto), municipal governments (cities, towns and villages) and public corporations (Japan Highway Public Corporation etc.). These clients verge on “producers”-rather than “buyers” of engineering service. Therefore, in-house designers have traditionally taken on fairly important roles in public works.

- **Designers in engineering consultant company.**

  Because strong public works clients possessed high competence for designing, the development of engineering consultant companies was considerably delayed in Japan. However, demand for design services grew with the rapid increase of public works construction since the 1950s. The number of registered engineering consultant companies rose from 226 in 1964 to 2,893 in 1996. In some cases, engineering consultants take part in the planning stage of a project; however, in general, their business is restricted to preparing design documents and monitoring construction.

- **Designers in design division of construction company.**

  Most large-scale construction companies in Japan, have their own design divisions to satisfy the needs of private works. It is usual/typical that private clients (owners) negotiate with only one party during implementation of their project under Design-Build (DB) contracts. For public works, design and construction are separated, in principle, in order to pursue fairness and transparency. In some cases, however, design divisions of construction companies are requested substantially to carry out a part of Designing for public works.

THE ROLES OF CLIENT FOR SAFETY AND HEALTH DURING DESIGN PHASE

It is important to pay more attention to construction safety and health from the early stages of project. Even though many conditions cannot be completely clarified at the design phase (e.g. soil conditions), it is necessary to identify the safety and health risks at the design stage as much as possible. The client has information in terms of preliminary conditions: thus, he can consider construction safety and health at the planning and design phase. Other necessities that the client should contribute for construction safety and health are outlined below.

- The client has decision-making authority on securing a sufficient budget for safety and health and setting up a suitable term for construction work. These are two extremely important factors affecting construction safety and health management during the contractor's implementation of the project. The same can be said in case of major design altered by client.
- Since many clients are government agencies for public works, they should automatically be responsible for public protection and welfare.
- In the future, Japanese public works will enter a period of demolition and renovation. The weight of new-construction investment in all public investment will fall from 79% in 1997 to 51% in 2010, 38% in 2025 and 8% in 2050, individually (Y. Kimura, 1998). In accordance with this, future planning and design for construction should be based on life-cycle aspects, in particular for public works. The attitudes of clients and designers for construction safety and health should be reformed.

On the other hand, to improve design constructability, which is closely related to safety and health performance in the construction phase, benefits the client by enhancing productivity in general. From this point of view, it is acceptable that the client is allocated a portion of the responsibilities for construction safety and health management.

PROBLEMS IN DESIGNING FOR CONSTRUCTION SAFETY

There are some gaps between expectation and reality on designing for construction safety. To promote safety management, the Ministry of Construction developed a set of General Safety Principles in Placing Orders for Public Works in 1992. The Principles present the policy that the client, designer, contractor and workers should undertake safety measures based on their share of responsibility. Nevertheless, designing with sufficient consideration for construction safety has not been realized in practice.

The reasons for the gaps are:

- The insufficiency of technical experts within client organizations, one symptom of this is the reliance of public works (especially municipal government) on design outsourcing. On contract price basis, public works related contracts account for 85.9% in the domestic engineering consultant market in 1999 (Source: http://www.moc.go.jp/chojou/kanren.htm, for the largest 50 companies).
- Engineering consultants have not fully developed to meet the growing of business

demand. Japan's consultant industry lacks the necessary professionals who are well acquainted with detailed construction methods. Recently, consultant companies are hiring experienced engineers from general construction companies to compensate for their lack of in-house skilled staff.

- Due to restrictions from the nature of public works, clients prefer using traditional types of contract but not some new types such as Design-Build. This means that the design division within construction companies may not be able to fully apply their abilities for safety management.

In traditional public works, there is nearly no feedback route between construction and design. Engineering consultants are assigned to deliver drawings, and have a right to demand the payment. Design alterations are later carried out by negotiation between client and contractor. As a result, the engineering consultant rarely receives feedback of previous projects from client or construction company (See figure 2). As shown in the figure, the consultant is literally "out of the loop".

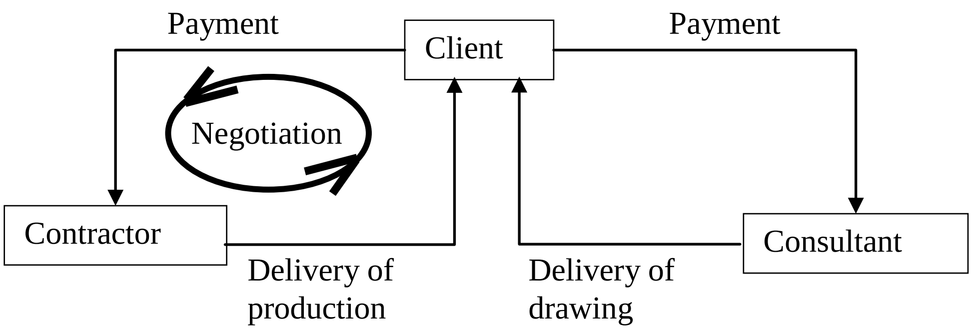

Figure 2 the relationship among client, contractor and consultant in traditional public works

SUGGESTIONS

To overcome the existing drawbacks, the roles and responsibilities of clients, contractors and designers should be reconsidered. Constructive contributions from the client side are expected. The public works clients should either highly regard design for construction safety and health using in-house engineers, or should establish a

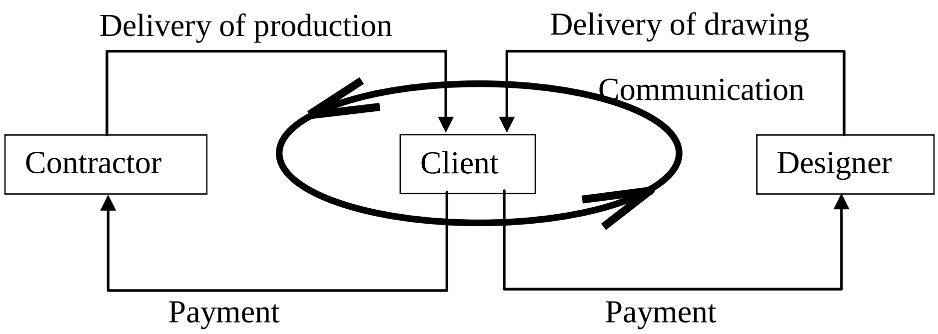

Figure 3 Establish a platform for designing

communication platform for designer and contractor in the case of outsourcing design.Considering their technical competence, central government, its agencies, and public corporations can apply the method as figure 3 shows. The point of this method is to create a direct contact route between designer and contractor. Local government and municipal government, lack in-house capacity, hopefully apply the other method (See figure 4). The Construction Management (CM) company is required to play a significant role in this frame.

Unfortunately, under the traditional public procurement system in Japan, these two methods are difficult to function effectively. The reasons are: 1) design and construction is separated; 2) sequence of design and construction, whereby design must be complete before bidding for construction. The methods fit better with DB contracts, fast-track projects and design alterations. The Japanese public procurement system is under pressure for reexamination today. It is a great opportunity to erect a new system of designing for construction safety and health.

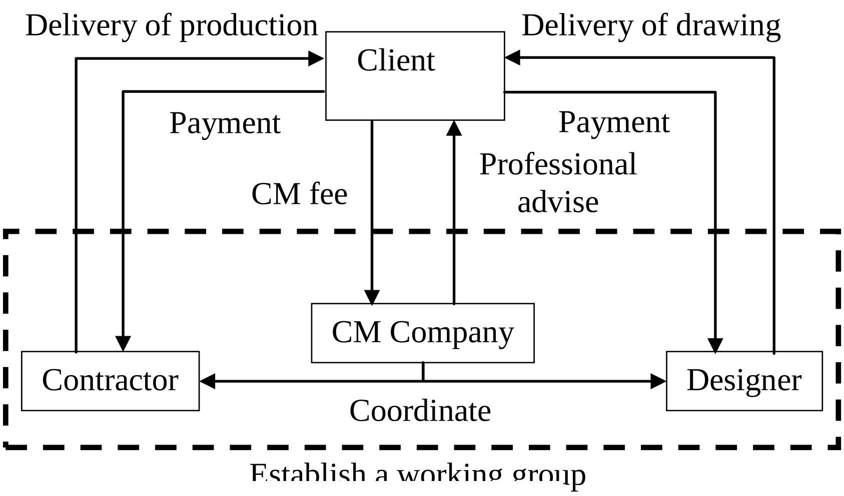

Figure 4 Establish a platform for designing

CONCLUSIONS

Although there is no doubt that the liability of contractor and worker's self-protection obligations are serious, public works clients and designers should bear their due responsibility for a comprehensive system of construction safety and health management. As usual, the construction stage is emphasized for construction safety and health; however, attention is focused on design phase (even planning phase) recently. With these issues, the designer is required to realize design for construction safety and health: meanwhile, the public works client should support the designer to reduce overall occupational risks. In short, well-balanced allocation of responsibility among all participants is desirable to attain further improvements of construction safety and health management in Japan.

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POTENTIAL CONTRIBUTION OF CONSTRUCTION FOREMEN IN DESIGNING FOR SAFETY

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ABSTRACT

The improvement in construction worker safety performance has taken place without the active involvement and participation of the design profession. When it has been successful it has been a top-down process in the individual construction company. It has been established that the best way to reduce safety risks in construction is to eliminate or minimise them. Designers are well placed to make this contribution. Construction foremen are the vital links in the construction process transforming designs into real facilities. Through their daily planning activities on construction sites they have a significant influence on the safety and health of their work crews. Since almost 50% of all accidents in construction fall within the areas of control of either of the designer and foreman, it makes sense for them to engage in dialogue before, during and after the execution of construction projects. This concept is not in lieu of top-down construction safety management, but in addition to. In this way, designers might be able to design buildings which will be safer to construct. This paper examines the contribution of designers and foremen to the designing for safety effort.

Keywords: Designers, foremen, hazards, safety performance, worker safety

INTRODUCTION

The leader of US National Institute for Occupational Safety and Health for many years (Director, 1981-93), J. Donald Milner, lamented the persistently dismal reputation of the construction industry with respect to construction worker safety and health with the following statement:

> *"Deaths from injuries in construction ….. an epidemic - a tragic, unnecessary epidemic ."* (CPWR, 1993, pg. 2)

Riley Bechtel, President and Chief Executive Officer, Bechtel Group not only served an indictment on, but also a serious challenge to, all participants in the construction industry by stating:

> *"I sincerely believe all accidents are preventable,"* (CPWR, 1993, pg. 2).

Both these statements imply that a serious effort needs to be made to improve the safety record of the construction industry by all the participants in the construction process. In this paper we examine the contribution that two of these participants, namely construction foremen and designers, can make to the prevention of construction worker accidents through designing for safety.

DESIGNERS AND WORKER SAFETY

While there have been some improvements in safety performance, this improvement has taken place with the design profession not being an active participant (Gambatese, 2000). According to MacCollum (1995), the primary and most effective method which should be used to reduce safety risks is designing to eliminate or minimise hazards, suggesting that designers are well placed to have significant impacts directly and indirectly on construction site safety performance. While the responsibility for providing a healthy and safe work place for construction workers has traditionally been the sole responsibility of contractors, designers influence the health and safety performance of projects and should consider and incorporate health and safety considerations in their design (Tenah, 1994). Introducing safety and health considerations from the early design and engineering phase of the construction process can improve productivity when construction actually takes place. Unfortunately there is too little consideration of safety and health in the design and engineering communities (CPWR, 1993).

In recent times, there have been several attempts to redistribute the responsibility for safety of construction workers among various participants in the construction process (Smallwood and Haupt, 2000). Of particular note are the Construction (Design and Management) Regulations in the United Kingdom which were enacted in 1994 with the objective of directing designers to address construction site safety as the design is being developed (CDM, 1994). In terms of this legislation and the European Council Directive of 1992 on the implementation of minimum safety and health requirements at temporary or mobile construction sites (92/57/EEC, 1992), designers have to be sufficiently competent to appreciate the impact of their designs on safety and health aspects. Whereas designers were not previously extensively involved in giving advice about systematic consideration of safety and health issues, they are now required to avoid foreseeable risks as a duty for all construction projects in Europe and the United Kingdom (Coble and Haupt, 1999; Haupt and Smallwood, 1999).

Whereas designers as the third party to the typical contracting agreement chose, in the past, to distance themselves from the responsibility for safety during the construction phase, they are now increasingly being asked by owners to become involved in the planning for safe construction sites. This stipulation by owners has sometimes required designers to modify their designs. Understandably design professionals had very little to do with construction problems which did not directly affect the erection and/or function of the designed structure. They merely represented the building owner, making visits to the construction site to ensure that the structure itself was being erected correctly. They had very little to do with the actual construction process. Further, most design codes do not hold designers accountable for construction site safety, and there are very few existing reference standards to guide designers in making important design decisions and choices for the benefit of improved construction worker safety. Typically, designers have received little formal education and training about construction worker safety. In the United States, the Occupational Safety and Health Act of 1970 does not place any great responsibility on designers, regarding any efforts by them to address construction worker safety as being purely voluntary.

CONSTRUCTION FOREMEN AND SAFETY

While construction foremen have tough and challenging jobs, they are also the vital links in the construction process, serving to transform facilities from design drawings to actual physical facilities. In this way they form the backbone of the construction industry. Their importance to the construction process cannot be minimised.

They play possibly the most important role in establishing and maintaining construction worker safety on the job site (Hinze, 1997). On a daily basis they plan out the daily activities of their workers, resulting in a significant influence on the safety performance and productivity of their crews. They are usually the first to become aware of potentially hazardous situations that might arise on the job site due to design requirements with regard to materials to be used and construction technologies to be employed. They are often also the first to be notified when an accident, injury or fatality occurs.

Construction foremen have usually come through some form of apprenticeship program during which they developed many skills. These skills engender confidence in themselves and their ability to perform their tasks efficiently, productively and safely. Further, foremen have been trained in the proper use of tools, plant and equipment. Generally, foremen are craftsmen who have worked their way through the ranks to become foremen. In this way most foremen have a wealth of experience earned over many years in the industry. Additionally, they potentially become role models to those whom they supervise on a daily basis.

Training in occupational safety and health in the workplace has become the norm for construction foremen. During this training they are equipped to recognise potential and real hazards on the construction site. They are also trained in the best ways to cope with the exposure to these hazards. They are made aware of emergency procedures in the event that accidents should occur.

While the planning of a construction project is not normally authored by the construction foreman, they supervise planned and repetitive work. They interpret the intentions of the project designer from the drawings and transfer this information to the members of their work crews. Consequently, they might have to modify their methods of supervision in order to make the final product more efficient and of a higher quality.

DESIGNERS, CONSTRUCTION FOREMEN AND SAFETY

More than 50% of occupational accidents on construction sites in Europe were attributable to unsatisfactory architectural (design) and/or organisational options, or poor planning of the works at the project preparation stage (Coble and Haupt, 1999; Haupt and Smallwood, 1999). Construction foremen can make significant contributions to the designing for safety effort, provided that designers recognise and harness their skills, site experience and knowledge base. The contribution of foremen to improved worker safety performance would be optimal in the areas of project planning, construction means and methods, material handling, task co-ordination, and worker training when new technologies and materials are introduced. Further, designers could use this wealth of knowledge and experience in the development of more construction worker safe designs by consulting with foremen continuously during the actual construction of the facility - the idea being the continual evaluation of the existing design from a purely safety and health point of view. Designers might consider debriefing foremen on the safety and health aspects once their projects are completed with a view to reviewing their designs. The findings of the debriefing could be used to make future designs safer and healthier for workers.

Areas of expertise in which foremen could provide input as a result of their training and daily responsibilities on the job site include *inter alia* information on:

- Hazards associated with the use and handling of various materials;
- Hazards due to the incorrect sequencing of operations and activities;
- Safer sizes and working heights for windows, doors, openings and other components;
- Scheduling to avoid undue hazardous schedule compression;
- Planning site access and exit positions;
- Location of cranes, hoists, and concrete batching plants;
- Site transportation routes; and
- Maintenance procedures and considerations.

Alternatively, designers could utilise the services of foremen with excellent safety records to review their designs as they are developed to ensure that the facility under consideration could be built without endangering the safety and health of construction workers. In this way, designers are able to draw on the expertise of contractors to make their designs safer. Potential hazards could be identified earlier and alternatives explored to reduce exposure to them.

The separation of the design process (realm of designers) from the actual construction process (realm of foremen) has perpetuated problems in communication, co-ordination and interpretation between participants in construction. By reversing this trend of fragmentation through mutual intercourse and exchange of ideas, it is hoped that improved communication, co-ordination and interpretation will be the natural outcome. For this to happen, designers and foremen need to engage in constant constructive dialogue.

CONCLUSION

It is apparent from this discussion that designers and construction foremen can both make a contribution to improving the worker safety performance of the construction industry. However, it will be necessary for each to move away from their traditional and exclusive roles in the construction process to make this happen. It is possible for designers and foremen to make contributions to the designing for safety effort during the pre-design, design, project execution or construction, and maintenance phases.

While it is unusual for designers and foremen to work together in this way this level of cooperation is justified if lives are to be saved on construction sites around the world.

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INTEGRATED DESIGN FOR SAFETY: FROM INFORMATION AND DESIGN SIMULATION TO CONTROL DURING EXECUTION.

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ABSTRACT

As far as a substantial percentage of accidents on construction sites can be put down to wrong design choices or poor programming of works it becomes indispensable to integrate the activity of design and programming with methods and tools that enable identification, solution and the much desired elimination of situations of danger for workers. According to this the latest version of the Italian interpretation of EEC Directive 92/57 re-emphasises the need to integrate the measures aimed at safeguarding workers right from the very first moments of the design process.
In order to achieve such objectives, it is necessary for the professionals involved in "design for safety" activities to have at their disposal a complete set of useful information for translating design decisions into effectively applied operating procedures. Such operating procedures thus come to represent that simulated phase of the intervention that enables validation or otherwise of the design choices in the perspective of achieving safety in the executive phase and that enables "visualisation" of potential situations of danger by integrating the constructional choices with possible scenarios of programming of works. The purpose of this paper is to analyse what types of information the planning-phase co-ordinator needs for drawing up the safety plan, and, to set up an integrated design activity. Moreover investigated will be the types of operating tools that may be of assistance in the activity of design and coordination, also in the executive phase, both as data base of operating procedures and as tools for visualising executive scenarios by means of 2D and 3D computer graphics.

Keywords: Integration, safety, design & construction, IT, simulation

INTRODUCTION

The problem of safety in temporary or mobile building sites cannot and should not be tackled simply when work on site is already underway. Statistics disclosed by the European Union on the principle causes of accidental death reveal that these consist mainly of inappropriate decisions at an architectural and managerial level, inadequate planning of works and co-ordination problems linked to the presence on site of more than one contractor. On the assumption that the principle cause of accidents on building sites is attributable to design errors (35% of total accidents), a decisive step was taken with the passing of European Directive 92/57/EEC which was intended to have a decisive effect on the design and management stages of the building process.

Looking at the situation in Italy, this awareness materialised with the introduction of two legislative enactments: legislative decree no.494/96 (implementing EEC Directive 92/57/EEC) and legal enactment no.415/98 (more commonly referred to as the "Merloni Ter" law) which regulates tenders in the public works sector. The first decree (amended and up-dated in November 1999) reiterates the need to involve professional figures dealing with safety operations (the Project Supervisor and Safety Co-ordinator at the project preparations stage already introduced by the European Directive) right from the very first stages of the design process. In this way, the designer is given guidance with his work, allowing him to establish the executive implications of the decisions he makes at the project stage and thereby evaluate whether such choices are compatible with safety requirements. At the same time, guidelines for the scheduling of works can be defined, on the basis of the compatibility, in terms of space and time, of the various operations to be carried out on site. The "Merloni Ter" law also confirms the importance of the design as the central and fundamental element on which the quality of the construction depends and which, as such, must incorporate the papers necessary for safety planning. This paper will therefore deal, first of all, with the legislative measures referred to above, and then describe the roles and functions of the professional figures responsible for providing the designer with back-up in tackling safety aspects during the execution stage. Data available to the Project Supervisor and Co-ordinator during the design stage will also be analysed, representing information of essential importance to the development of an effective safety plan. This information will then be reprocessed using appropriate methods such as CAD, thereby providing a useful toll for the visualisation and simulation of critical aspects of work on site, as early on as the design stage.

DECISIVE MOMENTS IN THE BUILDING PROCESS: THE ROLES OF PROJECT SUPERVISOR AND SAFETY COORDINATORS

As already mentioned in the introduction to this paper, the amendments made to the Italian enactment implementing Directive 92/57/EEC describe in further detail the functions of the leading figures involved in safety management acting on behalf of the Client, namely: the Project Supervisor, the safety Co-ordinator during the design stage and the safety Co-ordinator at the project execution stage.

The Project Supervisor

The Project Supervisor is the figure appointed by the Client to deal with the design, execution, or supervision of the works. Looking first at the design stage, the role of the Project Supervisor is fundamental, involving the advance scheduling of the works throughout the various stages of execution. The initial schedule level, estimated in men-days, is used to establish the thresholds applying to the site which determine whether or not Safety Co-ordinators should be appointed (these thresholds have now been brought into line with the figures referred to in the European Directive). The Italian Government has also specified that this scheduling exercise, naturally aimed at safeguarding the workers during the execution of the works, must coincide with the making of technical decisions, the drawing up of the design and organisation of site operations. The moment chosen is obviously of strategic importance in order to pin-point any flaws in the project or contractual schedule which, if not suitably corrected at the appropriate time, could give rise to problems during the execution of the works or may necessitate variations while operations are already underway, thereby making it difficult to guarantee safe working conditions for the operators on site.

Safety Co-ordinator at project preparation stage (Planning-phase Co-ordinator)
Alongside the Project Supervisor, the Safety Co-ordinator at the project preparation stage plays an important role, ensuring principally that the design takes account of safety requirements on site. Apart from processing the contractual safety documents (Health and Safety Plan, Safety File), the Co-ordinator is also responsible for supervising every step of the design stage in order to ensure that the site works are executed under safe conditions. With this role in mind, an important amendment was made to the original text of legislative decree no.494/96 which provides that the Co-ordinator at the project preparation stage be appointed either by the Client or the Project Supervisor when the "executive project" is drawn up. The "executive project", expressly defined in legal enactment no.415/98, is the most detailed design stage based on progressive levels of technical development. The executive project is in fact defined as a project drawn up in accordance with the "final project" (the preceding design stage required to obtain planning permissions) and defines the works to be carried out in full detail; it must therefore be developed with adequate definition to allow every element to be identified in terms of form, type, quantity, size and price. It is clear that if the Co-ordinator is appointed at such an advanced stage in the definition of the design, then it is no longer possible for information to be exchanged or for this figure to combine forces with the designer and thereby put together a safety plan project. In order to avoid these problems, which also affect the drawing up of the Health and Safety Plan, the new version of legislative decree no.494/96 provides that the Co-ordinator at the project preparation stage be appointed right from the beginning of the design stage. In this way, a foundation is laid on which design operations can then be developed hand-in-hand with the safety planning process and the most can be made of the services provided by the Co-ordinator.

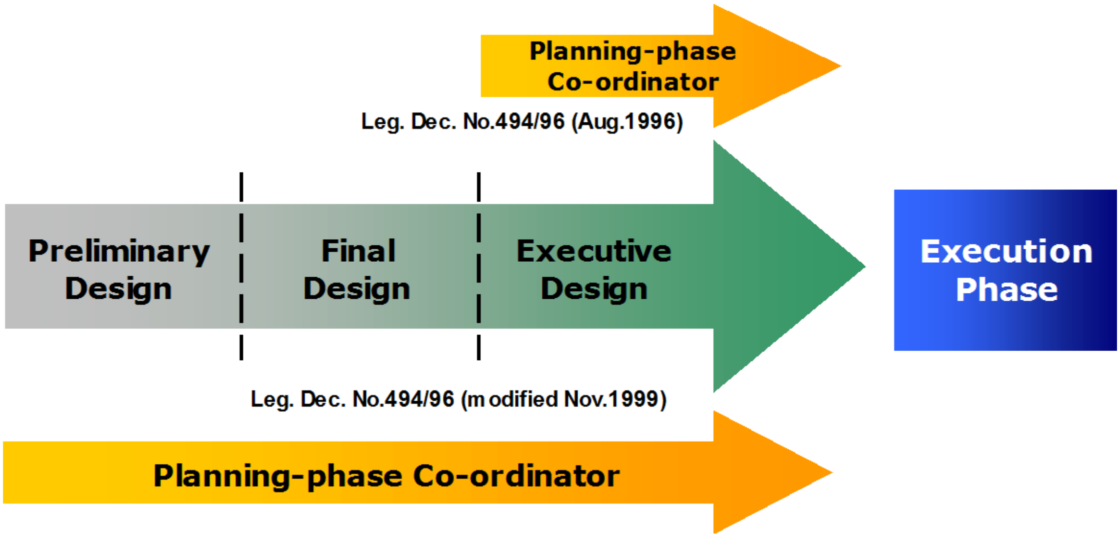

Figure 1 – Planning-phase Co-ordinator's activity through different design stages

DECISIVE MOMENTS IN THE BUILDING PROCESS: SAFETY INFORMATION AND DOCUMENTS

An examination of the structure of the documentation required for safety planning, as laid down by the new version of legislative decree 494/96, reveals how the work of the design Co-ordinator and that of the Project Supervisor can be integrated and combined with the activities carried out during the design stage. The papers making up the safety documentation are as follows: Prior notice, Health and Safety Plan; Safety File. Unlike the previous version of the decree, the contents originally envisaged for the General Safety Plan must now be included in the Health and Safety Plan. The analysis and risk's assessment, safety procedures and safety costs estimate must now therefore include information regarding management, preparations, procedures and minimum safety requisites applying to the specific site plant. The contents of the Health and Safety Plan must then be used to draw up a technical report and instructions connected with the complexity of the works to be executed and with any critical stages in the construction process. It is quite clear that the responsibilities of the Project Supervisor in connection with work estimates and scheduling, and the activities of the planning-phase Co-ordinator relating to the drawing up of the Health and Safety Plan and the Safety File, are closely linked to the quantity, intensity and level of information available during the design stage. In particular, as part of scheduling exercises aimed at estimating the duration of the works as a whole and then assessing how long the works are likely to take and evaluating the interaction of individual operations carried out simultaneously, the Project Supervisor requires the following information:

1. The final version of the project in order to identify precisely the characteristics of the works, such as surface areas, volumes, distances, heights, materials used and techniques adopted;
2. Estimated measurements applying to the works with items described separately from the works as a whole;
3. Codes of practice which identify the executive methods used for each operation and the number and quantity of human and material resources required.

The estimated measurements must be sufficiently detailed to allow the Project Supervisor to identify the items making up the works together with the quantities required which, multiplied by the unitary resources involved will produce an estimate of the duration of the works. This function should help the designer draw up a complete and exhaustive set of documents, thanks to the assistance provided by the Project Supervisor. The Code of practice, on the other hand, should basically provide a full, detailed description of every stage necessary for the execution of construction works or the setting up of an individual construction element without overlooking information regarding the safety conditions under which the works are carried out. It is not the designer or the Project Supervisor who is responsible for drawing up these codes of practice, but a legislative body, association operating in the sector or a university department that is commissioned to carry out the task. There is no doubt that such an instrument would also make the designer's job much easier, allowing him to focus on the executive methods adopted in connection with the design he has created and, taking the works as a whole, to modify them whenever they are incapable of providing adequate safety guarantees during execution. Bearing in mind that data regarding the concrete production needs of the contractor are not generally available at the design stage, it is therefore necessary that the information referred is to be obtained so that the works can be scheduled on the basis of standard resources.

Apart from the actual management capacity of the contractor and any sub-contractors, the Co-ordinator requires detailed information in order to draw up the Health and Safety Plan and the Safety File. The Co-ordinator must therefore be given copies of the project in all its various stages, from the preliminary to the executive version, in order that he be able to pin-point any general problems affecting the site, as well as establish the specific safety requirements applying to the execution of each construction element.

An important new measure, which does not appear in Directive 92/57/EEC, but is introduced by legal enactment no.415/98 (Merloni Ter) and referred to in the new version of legislative decree 494/96 is the Safety Operating Plan.

The Safety Operating Plan is a document which the contractor must draw up with specific reference to the individual site concerned. In this document, the contractor is required to plan the safety measures it will apply as part of its own independent decision-making, and to take responsibility for the management of the building site and the execution of the works. The information contained in the Safety Operating Plan is therefore determining in the drawing up of a full, coherent Health and Safety Plan. This type of operating plan cannot always be made available however, given that the contractor has not yet been identified when the Health and Safety Plan, an integral and binding part of the building contract, is drawn up (the tender process not yet having been completed). In such a case, both the Project Supervisor and the Safety Co-ordinator at the project preparation stage will have to put what has been written and prescribed in standard terms in the Codes of practice and taken from the technical information provided by the producers into context, on the basis of potential execution scenarios.

SIMULATION OF BUILDING WORK: OPERATIVE INSTRUMENTS

The use of computer graphics to visualise the works carried out: the pre-design of the building site

When drawing up the safety documents, the design Co-ordinator is faced with an extremely large number of variables to be evaluated. It is therefore useful to divide up the design of the building organism into two distinct stages: the site pre-design and design stages. The pre-design stage can be developed on the basis of the executive project whilst the site design must be based, in terms of minimum safety requirements, on the actual production needs of the contractor with reference to the indications given by the company in the Safety Operating Plans. When tackling the site pre-design, the design Co-ordinator must first of all identify the relevant production requirements, describing the individual working places on site; these are identified with reference to categories of construction operations compatible with each other in terms of space and time and defined with reference to specific production technologies, work management models and the skills of the workers assigned to deal with them. In this way, the pre-design of the site, as part of the general design process, can be used to analyse the compatibility of activities within the same category, in terms of space and time. On this basis, the building site organism can be identified as a “macro work area”, in turn made up of micro work areas dealing with individual operations. The macro work area-building site may interact with a number of external organisms readily identifiable in plans forming part of the urban surroundings. These include, for example, roads, adjacent buildings, plant engineering sub-structures, overhead electrical cables. For the purposes, of controlling not only safety conditions on site, but also its general production and running, a wide range of interactions between the site and its external surroundings must be evaluated, as well as interactions between different micro work areas within the site itself. By producing lay-outs of the works at various stages of progress, computer graphics can be used to illustrate how the safety of the workers can be affected by the methods used to manage the site, depending on how its various elements interact during the execution of the works. By visualising the macro work area and studying a plausible plan for the site, the following conflicts, in terms of space and time, can be identified:

- conflicts with the external road network serving the site;
- conflicts in terms of space between the activities carried out on site and the adjacent urban centre;
- conflicts affecting infrastructures and engineering plants which may actually divide the plant structures.

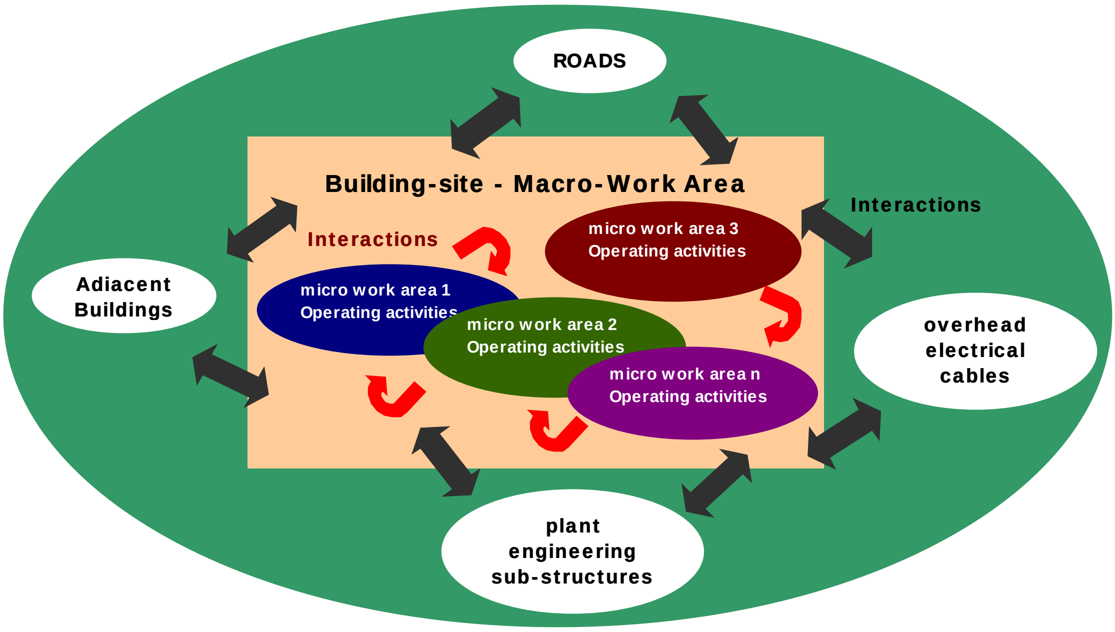

Figure .2 – Construction Site’s pre-design: identifications interactions between site and surroundings and between operating activities.

The results obtained by combining alternative executive solutions can be submitted to the contractor when the contract is being drawn up, thereby offering the company a set of guidelines in its choice of construction firm to take on the work which reflect its actual production capacity. Once the pre-design has been developed, and the Project Supervisor has started to schedule the works, a series of instantaneous representations can be created illustrating how the site can be managed on the basis of the plausible construction alternatives put forward by the Co-ordinator. This development, as part of an assessment of the performance of the various interacting work areas graphically represented, helps to identify any co-ordination problems stemming from conflicts in terms of space and time affecting the operations undertaken. These conflicts can in fact give rise to situations in which the best possible conditions can no longer be guaranteed, prejudicing not only the quality of the construction but also the safety of those working on it. Naturally these conflicts are heightened by the large number of working teams operating on site and the wide range of construction methods adopted, as well as the general difficulty of the work in course. By working on a more detailed scale, the working spaces can be visualised more effectively with reference to the equipment and machinery used during the various operations, thereby allowing the interaction between individual micro work areas to be evaluated. With this process, the design Co-ordinator can use computer equipment to speed up the analysis of the various alternatives applying to individual working areas involved in simultaneous operations and evaluate the feasibility of each solution in terms of safety and human engineering and if necessary, implementing safety measures for those concerned. This process can be further expedited with the use of special CAD instruments such as graphic documents or standard “blocks” which illustrate the equipment and machinery with the relevant measurements and/or working spaces and allow these to be adapted to the particular building site in question. It must however be reiterated that the benefits and ease of use offered by computer equipment cannot, and must not replace the rational and skilled work of the Co-ordinator who must be capable of translating the standard data graphically illustrated into practical solutions applying to a specific executive context.

3D modelling for full visualisation of the site.

As already pointed out in connection with the information and documents required to establish fully the safety procedures to be adopted and to out them into context in the specific building site under examination, it is important that the production and management potential of the contractor be determined. Unfortunately this type of information is not always available prior to the tender. The design Co-ordinator is therefore faced with the problem of examining the design in depth in a short space of time and then anticipating, on the basis of his speculations, any possible damaging or harmful events which might be associated with the working areas and operations envisaged. The difficulties experienced in making this type of prediction stem principally from the fact that the design and construction process tends to be broken down excessively, communication between the various figures involved often obstructed (designer, contractor, sub-contractors, suppliers, etc.), as well as the lack of fully defined construction details. This has an effect, not only on the building constructed, but also on safety conditions during the execution stage. In this context, computer graphics can be of considerable help both to the designer and the Project Supervisor and design Co-ordinator. In fact the three-dimensional representation of the building under construction, which is even more effective if linked to the progressive stages of the works, allows individual operations and works areas to be visualised and prefigured in greater detail, thereby pin-pointing the critical areas affecting the execution of the works. 3D modelling can therefore prove an extremely effective tool, integrating traditional graphic documents consisting of drawings, plans and section diagrams with information regarding the planning of the site. A 3D model in fact produces an overall view of the building, allowing it to be placed in the macro work area and facilitating the analysis of the site in its surrounding environment. By associating the applications relating to site structuring and management with traditional architectural modelling methods, used in Italy mainly for trade communication purposes, the task of pre-planning on the part of the designer, which represents the basis for the integrated safety design, is made considerably easier.

4D CAD: prospects and developments in the safety context

Amongst the range of operative tools offered by computer graphics and capable of providing an enormous instrumental contribution to the integration of safety factors in the design process, we find one of the most recent collaborative building design applications: 4D CAD. This instrument combines three-dimensional modelling with temporal dimension, namely a fourth dimension, thereby allowing the three-dimensional image to be visualised through its evolution in time. In building terms, this means that architectural modelling at a space dimensional level, can be associated with information obtained from work scheduling, thereby illustrating the development of the building, and of the construction site, at the various progressive stages of construction. The application of this tool in the European building sector is still somewhat limited (with the exception of research and applications developed in Great Britain and Finland), yet it is likely to have great scope, not only in Construction Management, but also building site safety management. In fact the most important applications offered by 4D CAD affect mainly time and cost management. Bearing in mind, however, the starting point is this system, namely its ability to simulate the works as early on as the design stage and thereby limit unforeseen events occurring on site, it is easy to imagine the development of this application to visualise conflicts in terms of space and time in a safety context. 4D CAD in fact represents an ideal means of placing the project within its real context, namely actual site conditions. Time simulation also allows any errors made by the design team to be visualised in advance and helps those involved in design operations to establish the sort of modifications which should be made.

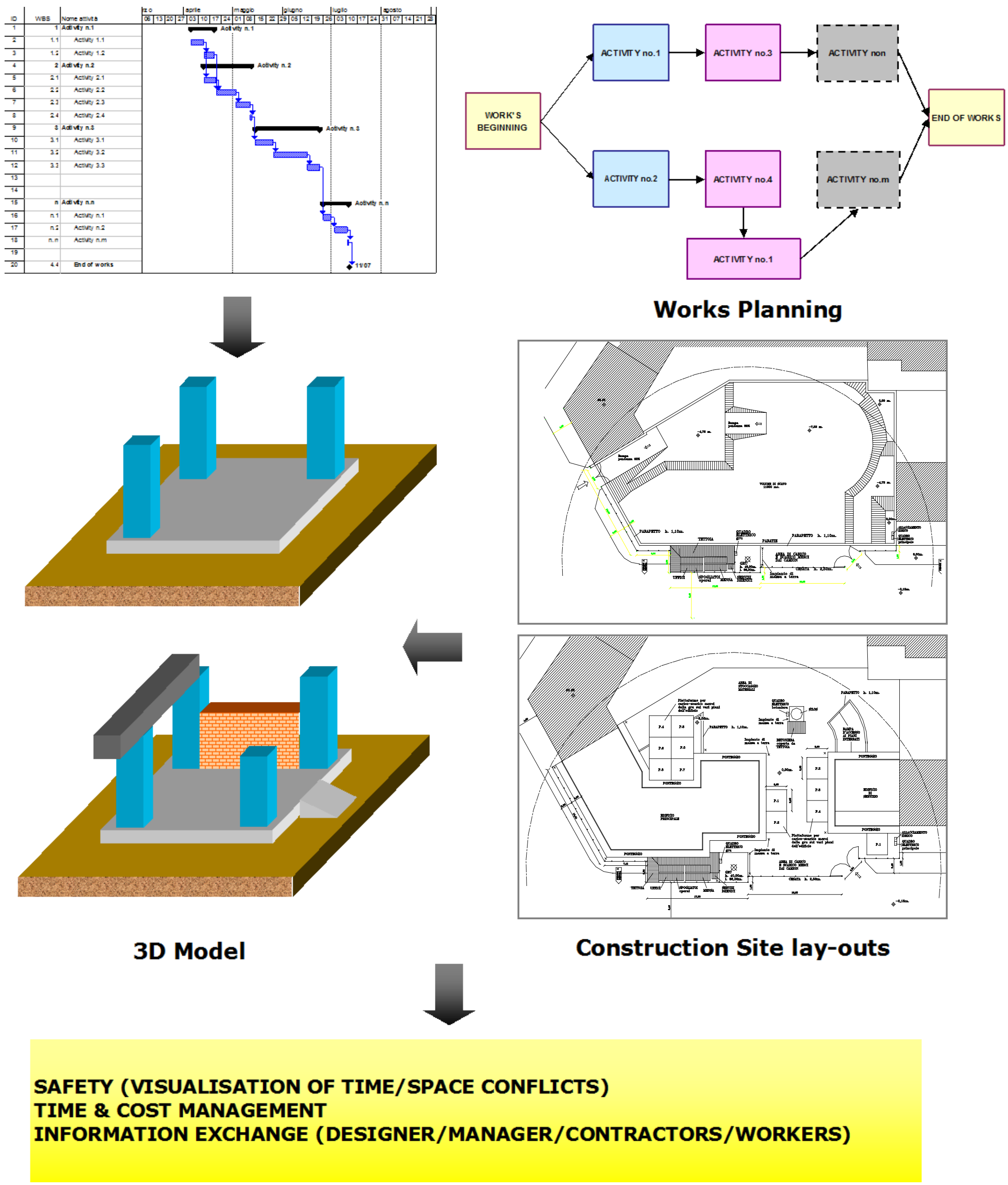

Figure 3 – Benefits from using a 4D CAD approach in design and management

Whilst three-dimensional modelling is used mainly to visualise the design, 4D CAD represents a management tool in the real sense of the word, capable of adapting to the needs of the various figures involved in the building process.

At a design level, three-dimensional visualisation requires the co-ordination and combined forces of the full professional team and the results obtained should therefore be more complete and consistent than a project composed of two-dimensional graphic illustrations. This team, increasingly involved in and aware of the realities applying during the execution stage, can also benefit from the immediate availability of a three-dimensional image, thereby realising what stage the works have reached and tackling decision-making with greater ease. They will also have the benefit of another tool with which to evaluate offers submitted by firms on the basis of the alternatives (in terms of time, costs and safety) they put forward. Another advantage offered by this type of visualisation is the ability to co-ordinate the work flows of different firms operating on site, assigning tasks and communicating with operators involved more rapidly. It is therefore possible to visualise the location and tasks of each individual working team while works are underway, thereby encouraging Co-ordination during the execution of the works. This type of tool can therefore be of great help at the execution stage to both the Project Supervisor, who is responsible for supervising the works from a safety point of view, and the Safety Co-ordinator at the project execution stage who up-dates the safety plan.

CONCLUSIONS

An essential requirement when developing a safety project during the execution stage is strict collaboration and co-ordinated exchange of information between the designer, Project Supervisor and the execution safety Co-ordinator. This objective, provided the various roles are not taken on by the same person, is further sanctioned by the modification to the Italian enactment implementing Directive 92/57/EEC dealing with the health and safety of workers on temporary and mobile building sites. These amendments in fact stress that safety planning, in this case the appointment of the design Co-ordinator, must be initiated as soon as work has been started to draw up the project and continue until the documents necessary for safety management on site have been drawn up. The work of the Co-ordinator is therefore set against a fragmented design background in which a number of different professional figures must operate. Safety planning is often affected by the lack of information regarding production conditions and site management methods adopted by the contractor. Safety professionals therefore find themselves in a position where they must structure and visualise plausible site alternatives. This gives rise, still at the design stage, to a sort of pre-planning exercise whereby any errors or inconsistencies in either the design or works schedule can be identified . In this way, a feed-back process is created whereby this type of incompatibility can be corrected and the design brought into a safety context. The instruments offered by computer graphics and virtual technology facilitate the visualisation process, allowing safety problems, affecting both planning at the design stage and management at the execution stage, to be identified on a large as well as a more detailed scale. Apart from the scope for combined use of software tools currently available on the market, naturally this should not lead to an excessive all-embracing use of assisted design programs, which overshadow the importance of the work carried out by the designer and Co-ordinator. In the light of the progressive development of computerised instruments which combines the graphic image with information linked to the management, scheduling and management of the works, complete, exhaustive design documents can now be obtained. This can all be guaranteed with the establishment of common platforms on which all the design figures involved can work together, ensuring, thanks also to the quality of the information made available, the quality of the project as well as the safety of the execution. Results should also be obtained at a execution level, provided the computer equipment used does not outstrip the actual capacities of the operators.

DESIGN SAFETY CO-ORDINATION IN METRO DO PORTO

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ABSTRACT

Large construction projects are an opportunity for further steps towards the implementation of Health and Safety Management Systems (HSMS). This paper introduces the system developed for the construction of Metro do Porto and addresses some aspects of Design Safety Co-ordination functions, as established in the EC Directive, Temporary or Mobile Construction Sites. An alignment approach to the existing Quality Management System has been followed using previous implementation experience at the contractor organisation. However, further integration among several management systems is expected in the future. The paper focuses on the contents of the Health and Safety Manual and General Procedures and attempts a comparison to corresponding quality documents. Follow-up design activities have been structured in a set of design meetings that involve the design team and take place throughout the design development. Design follow-up generates valuable material allowing for hazard identification and preventive measures to be introduced in Safety and Health Plans. These are part of the HSMS and accomplish Directive requirements as well.

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 METRO DO PORTO, NORMETRO should develop and implement a Health and Safety System (HSS) 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.

Accordingly, the HSS would constitute a set of organised methods of achieving these sated goals thus conforming the *usual definition* of a Health and Safety Management System (HSMS) [7].

HEALTH AND SAFETY SYSTEM

A well-established frame does not support the development of Health and Safety Management Systems in Portuguese construction industry so far. However, a standard for safety management has been claimed as *it could have some value as far as safety assurance is concerned* [3]. The framework for the development of a SMS has been suggested *by re-writing ISO 9000 standards directed to Occupational Health and Safety* and not to Quality [8].

When the development of the Health and Safety System (HSS) was decided, NORMETRO had already been developing a QMS in the frame of the ISO 9000 standards and good receptiveness of partners had been reported. Therefore, it appeared that the HSS 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 WSS.
- The QMS had been successive in getting management commitment from NORMETRO, 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 and future integration of the Environmental Management System (EMS) as well.

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 systems like these and this was also the philosophy adopted by NORMETRO in its organisational chart. Specifically, the integration of quality, safety and environmental management systems has deserved substantial reflection [4].

HEALTH AND SAFETY MANUAL

The Health and Safety Manual (HSM) is the main document of the Health and Safety System of NORMETRO. It provides the description and serves as reference in the implementation and maintenance of the HSS. The HSM has been designed with the following three main objectives:

- to advise the organisation (the consortium) of the safety policy that management has committed to adopt and to inform participants in the project of the means by which that policy shall be implemented;
- to demonstrate to the client that NORMETRO operates a Health and Safety System capable of assuring safety during design, construction and operation of Metro do Porto;

- to evidence purchasers and subcontractors the intention of NORMETRO in assuring that safety will be properly managed in all stages of project development.

The Health and Safety Manual has been built following the alignment approach mentioned above and fulfilling the requirements of the contract with METRO DO PORTO. It is organised into the following seven sections:

- Control.
- Safety Policy.
- Safety Objectives.
- Company Organisation.
- Functions.
- Safety Committees.
- Regulations.

GENERAL PROCEDURES

In the scope of the alignment approach mentioned above, standing instructions pertaining to the Quality Management System can be adopted for Health and Safety Management System as well. Accordingly, they have just been cross-referenced in the HSS. Moreover, general procedures for health and safety have been produced in order to detail specific areas as follows:

- **Safety follow up design activity:** Design Control is a main requirement of ISO 9000 series and specific documentation had already been produced for the QMS. Planning design procedures include design safety evaluation, which is a relevant item of design review, and it is also in agreement with guidance standard ISO 9000-2. However, it was concluded that the duties of the design team as established in the EC Directive 92/57/EEC could not be ensured with existing quality procedures. Therefore a safety and health procedure for design follow up activity has been produced.
- **Health and Safety Plan:** A safety and health procedure for the development of health and safety plans has been produced. This is parallel to existing quality procedure for quality plans. Both plans are essential to document how corresponding requirements are to be met in each particular project, but contents are different enough to call for separate procedures.
- **Health and Safety File:** This is a compulsory document under the Council Directive 92/57/EEC and a specific procedure was produced for its preparation.
- **Information and Training:** QMS does not have, yet, a procedure for training of all personnel in NORMETRO. So it was necessary to write a procedure covering this issue.
- **Safety Monitoring and Inspection:** Inspection and testing procedures had already been developed for the QMS in compliance with ISO 9000 series. However, monitoring and inspection of work conditions were not sufficiently covered and a specific health and safety procedure has been decided. This procedure focuses on hazard identification and preventive measures for construction activities so that safe work conditions may be assured.

- **Accidents:** A specific health and safety procedure has been developed covering action taking, information flow, reporting, recording, investigation process, etc..
- **Accident Analysis:** This procedure is about accident analysis comprising accident characterisation, causes, effects, classification and statistics.
- **Non-conformances:** Quality procedures for control of non-conforming product were not readily applicable to health and safety non-conformances, thus justifying a specific procedure to be developed.
- **Safety records:** This procedure has been prepared to identify the responsible persons for the implementation of the safety records and archives maintenance.

SAFETY AND HEALTH DOCUMENTS

Distinct plans are produced for each construction site, according to the procedure mentioned above and to the requirements of the EC Directive. Before the development of the HSS has started, most partners had already produced a set of detailed safety procedures covering hazard identification and preventive measures of typical construction activities. These documents are used as reference for Inspection and Safety Procedures although they have to be adapted to each specific site conditions.

FOLLOW UP DESIGN ACTIVITIES

Legal Frame and Usual Practices

The essential legal frame for follow-up design activity is the EC Framework Directive for Safety and Health and EC Directive for Temporary or Mobile Construction Sites. Although these legal requirements have long been adopted in most European Countries, previous research evidences that most design teams do not consider safety a major concern on the design phase [6].

This is a consequence of poor knowledge on safety issues as a result of lack of formal education and specific training about site safety [1] [5] and fear of increased liability [2] [5] [6]. This is changing however, and significant improvement has been felt in the last decade in Portugal, as designers are increasingly realising the need to include safety in their duties.

According to the Portuguese law, the design team must take into consideration the General Prevention Principles. This implies that designers should have a set of skills enabling them to identify hazards and corresponding risks, to reduce their possible effects by adopting effective design solutions, to specify remaing relevant hazards for the workers and to document their action. This requires a very large knowledge and it has been concluded that some guidance should be provided from the Design Safety Co-ordination team. Besides, the co-ordination of the design team duties in safety maters is also a legal obligation. This has mainly been understood as an actual follow up activity, not just checking the outputs of design. Following from the objectives of the HSS, this would be the only acceptable attitude complying with the contract between NORMETRO and the client.

Accordingly, the Design Safety Management Team acting as the Safety Co-ordinator conducts follow-up design activities. Actually, the extent and complexity of the project led to the designation of a team instead of an individual for the functions established in the EC Directive. This is an well-accepted solution for similar cases and not restricted by Regulations.

Way of action

The scope of the contract led NORMETRO to include in the organisation structure a specific management department for technical co-ordination of design activities. Therefore, it appeared convenient that Design Safety Co-ordination would work directly with this department, which comprises the following two subdivisions:

a) **System Engineering & Operation**, responsible for RAMS (Reliability, Availability, Maintainability and Safety) and for Tests & Commissioning, mainly aiming at the operation, safety included.

b) **Subsystem Engineering & Design Management**, for design of civil works, electromechanical and interfaces.

According to Regulations, Design Safety Co-ordination is mainly related to the latter subsystem but some issues also relate to the former. This is the case of design options that influence operation safety and usage of facilities. Integrating the design safety activity in the design management structure also allows for significant advantages: Safety becomes integrated in design, not a distinct subject and the duplication of co-ordination meetings with the same participants is limited. Accordingly, the design safety team is present at all design review meetings. Three types of design review meetings are foreseen:

- At the beginning of the preliminary phase.
- At the end of the preliminary design phase
- At the end of detailed design phase, before the release of execution drawings.

In addition, two other meetings were decided, in the pre-construction phase.

Co-ordination Meetings

The **first meeting** marks the beginning of the design process, and it is integrated in the ordinary design review meetings. The meeting is organised into two parts:

- The first part is a brief introduction to construction safety, covering issues like the relevant legislation, the role of health and safety co-ordination in the design phase, the contractual arrangements of NORMETRO, the Health and Safety System, the Design Control Record form, etc.
- The second part is a thorough analysis of main risks involved in the work execution on site, issuing predictive site conditions, near by obstacles, products and materials to be used, possible alternative safer construction methods, etc.

The **second meeting** takes place at the end of the preliminary design phase and is also integrated in the ordinary design review meetings. The conclusions of the previous meeting are first recalled, the Design Control Records are checked and a deeper analysis of construction activities is conducted. Specific works involving special risks are studied on a what - who - why - where - when - how bases. Examples are as follows:

> Can all the risks be avoided? Can the risks be controlled? What can be accomplished to reduce the level of the risks? Can something easier, lighter or simpler be used? Can a job be done at the ground level instead of in height? What technologies or equipment should be used to avoid the risks? What important information should exist in the Health and Safety Plan?

The **third meeting** is scheduled for the end of the detailed design phase and is still integrated in the design review meetings. The information on Design Control Records is collected and analysed, designers' recommendations to tender documents and to the Site Plan are discussed.

The **fourth meeting** is appointed prior to delivering design packages to the client. Related partner safety staff should attend. The aim is to present and discuss the Health and Safety Plan developed during the design phase, to evaluate the requirements for the Site Plan and to decide upon special requirements for the tender documents.

The **fifth meeting** is a pre-construction meeting. Construction safety staff from NORMETRO partners involved as well as the Construction Safety Management Team should attend. The aim is twofold: Firstly, to transfer health and safety information and documentation already produced and to review requirements for the construction phase. Secondly, to look for continual improvement of Health and Safety documents and to assure safety follow-up of sub-contractor procurement.

Records

Regulations do not force designers to record their decisions concerning safety and health. However, their specific knowledge of the project and their previous experience in similar jobs cannot be neglected and may fruitfully be used for safety improvement during construction. A formal record system easy to use and to monitor throughout the design phase has been created driving to more consistent approach to health and safety matters at this phase. Besides, information transfer to subsequent project phases is easier to get.

Accordingly, the design team is asked to use a previously structured format to register specific measures introduced in the project for risk limitation, as well as risks that could not be avoided during the design phase. Information is analysed during co-ordination meetings and need for further action is registered. This information is reflected in the safety documents produced during the design phase.

Figure 1 shows the Design Control Record form currently used in NORMETRO. Designers of each section of the project register their action on safety matters on the first four columns. Each row corresponds to a specific relevant design action for safety prevention or to a significant or unusual hazard for workers that must be considered by contractors. This is further discussed during the co-ordination meetings, leading to a classification on the control column. If a no compliance is detected, alternative design options should be envisaged so that hazards can be avoided, or their impact may be reduced. Further action is registered on another row and latter discussion will take place during the following meeting. Otherwise, possible complementary prevention measures may be decided and listed on the corresponding column. Relevant information for the Health and Safety Plan (HSP) and for the Health and Safety File (HSF) are mentioned on the last column. This record is successively updated throughout the design phase and information included in Health and Safety Documents. Design Control Records are passed to the construction phase during the fifth meeting mentioned above.

normetro	DESIGN CONTROL RECORD	Number	Page: /
	Site:	Code:	
METRO DO PORTO SA	Designer: Health and Safety Coordinator - Design: NORMETRO		
	Health and Safety Coordinator - Site: NORMETRO		

Number	Information on the activity	Hazards	Design prevention measures	Complementary prevention measures	Control C NC NA V	Information to HSP or HSF

Designer	Date:	Safety Management:	Date:	C – Complies; NC – Not complies NA – Not applicable; V- Verified

Figure 1. Design Control Record form

CONCLUSIONS

In Metro do Porto project a Health and Safety Management System has been developed following contractual obligations and the requirements of applicable Regulations. Current documents as required by EC Directives are essential but health and safety during the project life cycle could only be assured by means of a management system.

Total Project Management embodies full integration of management systems and this is also the philosophy of NORMETRO. However, an alignment approach to the Quality Management System has been pursued for several reasons, but eventual integration with Health & Safety and with Environment will hopefully be achieved.

The development of NORMETRO Health and Safety System has been conducted by the Design Safety Management Team. The system is already operational and has been audited, but continual improvement is required. Follow-up design activities are also under way, and are conducted by the Design Safety Management Team as well. However, evaluation is not still possible because few projects have already concluded the detail design phase.

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SITE SAFETY BY DESIGN

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ABSTRACT

Since HAZOP Studies were invented, design hazard identification has focussed mainly on health and safety in the operation and maintenance of completed plants. The CDM Regulations have now rightly challenged us to focus more attention on the health and safety of those who construct, and later demolish, our plants.

The first half of this paper compares and contrasts the hazard identification techniques such as HAZOP Studies and Hazardous Area Reviews which are focused almost entirely on safety in the finished plant, with others which can be used to focus on safety in construction such as:

- Layout Reviews can look at construction safety, as well as safety in the finished plant.
- Constructability Reviews enable Design Engineers to talk with Construction Engineers to evaluate alternative construction strategies, which are then translated into design philosophies.
- Electronic Model Reviews can be used to evaluate construction strategies, as well as to review the operation and maintenance of the completed plant.

These reviews are easy to carry out when the design is all being carried out inhouse. It is more difficult to get design subcontractors to design for safety in Construction.

The second half of this paper shows some results of this change in focus, and looks at case studies where the designers have helped to make construction work safer, such as the following:

- Hazards discovered by carrying out site surveys before starting the design.
- Doing erection work at grade, which might have been done at a height.
- Improving access to confined spaces, by modifying the design.
- Avoiding hot work altogether, when close to flammable substances.

Design Safety is a science in which we are constantly developing the techniques for improving health and safety on our construction sites, by design.

Keywords: Construction, design, integration, safety, HAZOP, HAZCON

INTRODUCTION

In the design of oil and gas facilities, and chemical and pharmaceutical plant, it is essential to have a systematic approach to the identification of potential hazards. This activity starts very early in the design stage, continues all the way through the construction stage, and into the commissioning and startup of the facilities. This process of hazard identification turns out to be very good business as it helps to improve quality and protect the project schedule, as well as avoiding unplanned extra costs.

The approach to hazard identification needs to be systematic, but it also needs to be subject to continuous improvement. Foster Wheeler Energy has had the opportunity to benefit from lessons learnt on a large number and a great variety of projects, which have been constructed in the Far East and the Middle East, as well as in Europe and the UK.

Foster Wheeler is frequently involved in EPCC (engineering, procurement, construction and commissioning) Projects, and therefore has the opportunity to integrate these operations in order to optimise the identification of hazards. In recent years one area in which we have found it essential to improve hazard identification during design, has been in the area of the potential hazards that may be faced by the workforce on construction sites.

We have also found it essential to feed the commissioning strategy back into construction planning and into the layout design and isolation philosophy. This has resulted in specific areas of commissioning and operations site safety being considered early in the design stage of the project so that appropriate steps can be taken to design the plant with the commissioning strategy well in mind. However, in this paper for the ECI Conference we will focus on improving safety during the construction phase of the project.

The current initiative to improve safety during construction has been encouraged by the introduction of the UK CDM Regulations 1994. At the same time the process has been championed by Foster Wheeler's determination to maintain and to improve upon the very successful safety record, that has been achieved during the last ten years on a worldwide project base.

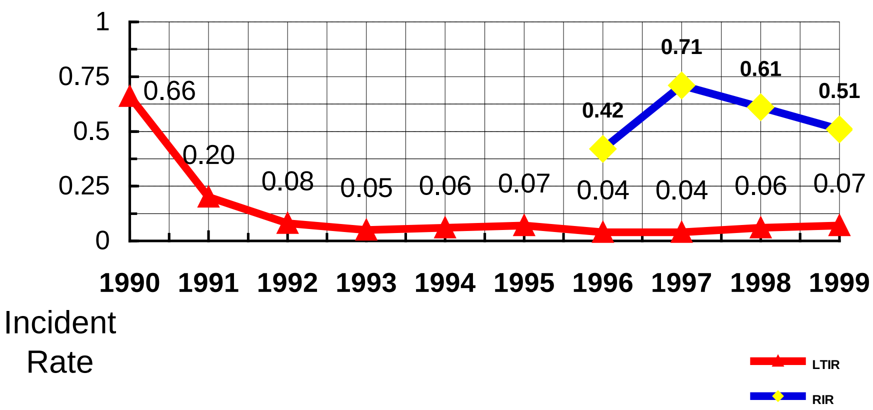

Figure 1: LTIR and RIR incident rates for UK construction

This improvement in construction safety has been assisted by the introduction of new integrated project management, and of new engineering tools, such as the use of electronic plant models, which have been used for the design, and then transferred into the field and used to support construction operations. The closer working relationship between engineering and construction that these tools bring are a major contribution to the low incident rate on the construction site.

The Foster Wheeler lost time incident record has remained at a very low rate for the last eight years, and this has caused us to measure other factors such as the total number of recorded incidents, and the potential of near misses. The rate of implementation of actions raised in Design Reviews has also been measured, in order to record and to achieve further improvements in safety performance.

The electronic transmission of engineering data from Process to Engineering and on to Construction gives consistency of information, avoids double entry and potential mistakes, and increases accuracy in the final installation.

Our approach to hazard identification has five key features which will be reviewed in turn in the next section:

- Timing
- Design Reviews
- Partnership
- Implementation
- Planning

FIVE KEYS TO THE CONTROL OF HAZARDS

1. Timing

Hazard Identification starts early very early in the design stage of the project, and continues through all stages of the project until construction has taken place. Over the last ten years we have carried out a series of Design Safety Reviews on each project, but the focus on safety in construction has not always been to the fore, in the design stage of the project.

The first change was made when it was decided that a Construction Manager or Construction Engineer should always attend the Plot Plan (or Layout) Review. At that time this review was often held early in detail engineering, before the Construction Manager had been appointed. One of the step changes we have made is that we now appoint our Construction Managers much earlier in the design stage of the project, so that they have time to participate in more of the design process.

Now, the Construction Manager, or the Home Office Construction Coordinator, attends many of our Design Safety Reviews, starting with the Process Safety Review, which takes place during the process engineering phase of the project. Our procedure for Process Safety Reviews has a checklist which contains some questions related to construction hazards, which need to be asked very early in the life of a project.

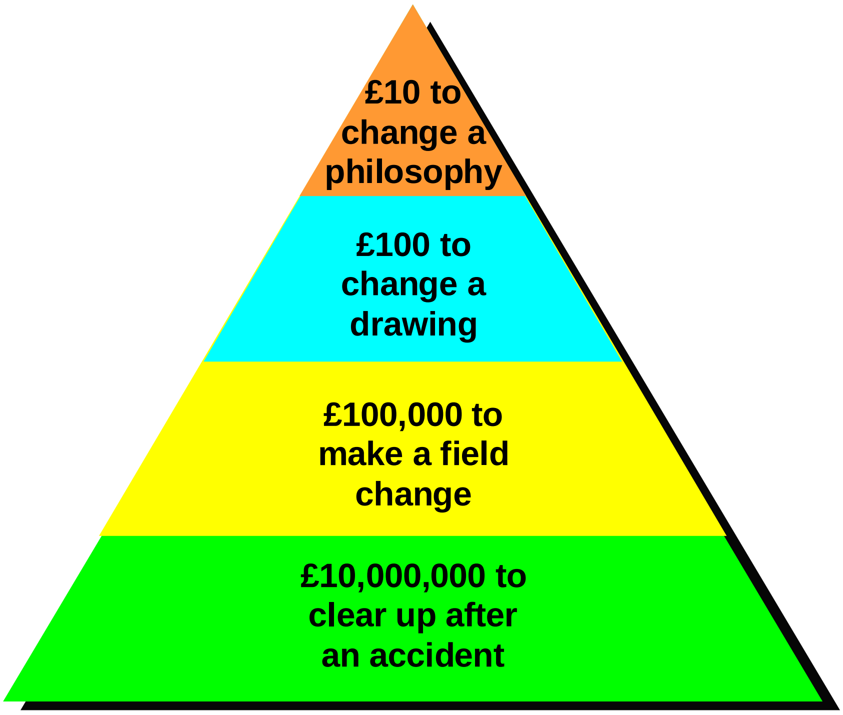

Figure 2: Accident cost triangle

Having started early, the process of hazard identification continues through the design phase of the project, and goes on right through the construction phase of the project, as described in the next section.

2. Design Reviews

A number of standard Design Reviews have been adapted by Foster Wheeler to focus more on the potential hazards in Construction as follows:

- Plot Plan or Layout Review now looks much more at the access required for construction as well as at the access required for operation and maintenance. It also looks at the proposed laydown areas for large equipment that may arrive on site and need to be parked until it is needed for erection. It may look at any potential problems with traffic which may result with construction traffic being added to existing traffic, especially on an extension to existing facilities, where production at these facilities may continue, while construction is undertaken.

- An electronic plant model is the most comprehensive way of defining how steelwork and piping, equipment and instrumentation, as well as electrical cables and junction boxes, relate to one another. It is vital that these very detailed designs are studied by Construction Engineers to anticipate any potential hazards in the construction process. Electronic models have on a number of occasions also been used to check construction strategies and the space available for lifting operations.

  The use of electronic plant models has had a very significant effect on construction because the clash detection facility sorts out the problems at the design stage, instead of requiring rework of installed equipment on the site.

- The Constructability Review was invented to provide a forum for design engineers to meet with construction engineers to discuss and compare design strategies with construction strategies, and if necessary to amend these strategies so that design safety and construction safety criteria are all satisfied at the same time.

It should be noted that there are some Design Safety Reviews, such as the HAZOP (Hazard and Operability) Study, which relate to hazards in operation and maintenance, and which do not relate to construction hazards. The Construction Manager therefore does not attend reviews like the HAZOP Study and the Hazardous Area Classification Review.

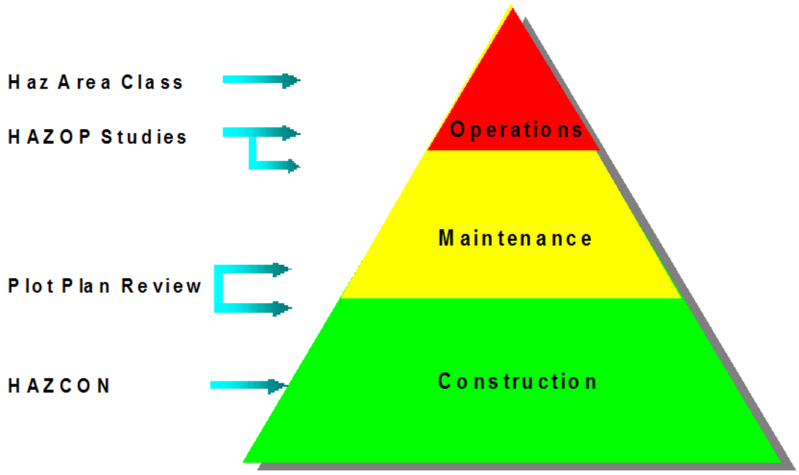

Figure 3: Construction, maintenance and operations triangle

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The Constructability Review was a good start, but it was found that improvements were required to allow multi-disciplined input and better communication. More recently Foster Wheeler has upgraded its HAZCON (Hazards in Construction) Process which is a multi-disciplined forum for carrying out a risk assessment of the construction strategies in three or more stages as follows:

- HAZCON 1 takes place during detail engineering with various engineers, commissioning and client representatives present. The purpose of the review is to ensure that the details of the design are consistent with the intended construction strategy, and that the level of risk is reduced by design, whenever possible, if it is not possible to eliminate it altogether.

- HAZCON 2 is a formal risk assessment of an individual sub-contractors construction strategy to ensure that all his activities are safely co-ordinated within the overall plan for all activities on the construction site. This review may be carried out in two stages, with the first before the award of contract, and the second after the award of contract.

- HAZCON 3 is a formal risk assessment of a particularly complex activity on the site, involving usually more than one sub-contractor, to ensure that all involved will be protected and kept safe from the activities of others, who may be working in close proximity.

So it is clear that all the way through the project from the start, up until the time when construction takes place, the identification of hazards on the construction sites is a significant part of our design and planning process.

3. Partnership
At all stages in the project there needs to be a partnership between those who are specialists in design, and others who are specialists in construction.

In the old days Engineering Department designed things and Construction Department constructed them! Those involved in the construction were not always happy with what had been designed, but they did their best, in spite of the difficulties.

Now through the above series of Design Safety Reviews and HAZCONs, the lessons learnt in the field on one project, are being fed back to the engineers in the design office on the next project. As a result the potential hazards and difficulties that can be avoided are avoided, building in the process a new partnership between the designers and the construction team.

As indicated above this hazard identification process is not just a single meeting between those involved. It involves a series of reviews so that, as the design is developed, the appropriate issues can be raised at the appropriate stages of the project, and the residual risks can be communicated to those who have to work on the site.

4. Implementation
There needs to be a clearly written description of the potential hazards identified in each review, and there is a thorough system to ensure that all the actions raised are implemented in a timely manner.

It is one thing to hold a series of review meetings extended over the life of the project. It is another to define the actions required clearly, and then to implement them into the design, or into the construction strategy, as appropriate.

Various systems have therefore been set up to ensure that the actions raised at each review, are properly defined, that each one has a named owner, and there is an agreed date by which the action needs to be taken. More than that, there is a checking and auditing process to identify the owners who fail to complete their actions on time, or who fail to carry out a satisfactory implementation of the action.

In Foster Wheeler each project has to produce an internal monthly report on exactly how many actions have been raised so far, and how many actions have been closed out. A league table is then produced to publicise internally any project that has actions that were raised more than three months ago, which have not yet been actioned. This league table goes to all Project Managers as well as to the Directors responsible.

5. Planning
Construction Planning begins with a visit and a comprehensive site survey, which includes a study of the possible access routes for bringing large and heavy equipment onto the site.

There is a deliberate effort to increase the ratio of pre-planned work to unplanned work, on the construction site. Detailed planning is required to address the sizes of cranes that will be needed on the site and the use of, for instance, a common scaffolding contractor, as well as the overall subcontracting strategy.

In order to make a more effective contribution to hazard identification in the Design Reviews, it has been found necessary to carry out these construction planning activities, and to prepare a preliminary construction schedule and an outline construction strategy, before the Design Reviews and HAZCONs begin.

The process of carrying out this detailed planning of construction activities well before work starts on the site, has by itself caused us to identify far more potential hazards, and to take early action to eliminate and to reduce these hazards as far as possible. This supports the underlying intention to increase the ratio of pre-planned work to unplanned work

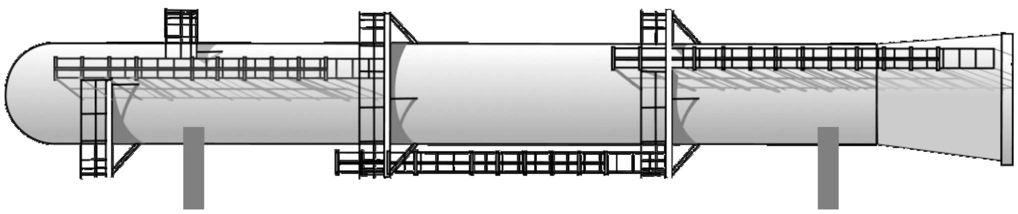
WAYS OF REDUCING THE LEVEL OF RISK

Some of the techniques evolved for improving site safety by the above process are as follows:

1. Increasing Links between Engineering and Construction
The increasing of the communication between engineering and construction has helped to define how and when information is needed to reduce the potential for unplanned work. One simple way of improving this communication has been to locate Engineering and Construction Management physically in the same area.

2 Effective use of Site Surveys
The site needs to be surveyed at least in outline, before significant progress is made with the design. It will need to be surveyed in more detail later. Equipment needs to be designed to be of such a size that it can be transported and erected without undue hazards to personnel. Limitations on the size or the weight of equipment needs to be known before the design is developed too far! The accuracy of information about existing installations is considerably enhanced by the use of photogrammetry and lazer measurements.

3. Reduce Working at a Height
Various techniques have been evolved for reducing the amount of work at above say three metres above grade. The dressing of columns while horizontal is well known. Foster Wheeler has also been involved in the construction of major modules lying on their sides, so that the upper decks are much nearer the ground. We have also pre-assembled large sections of elevated platforms and equipment on grade, before lifting the complete assembly into the required elevated position.



4. Avoiding hot work on a Refinery

In recent years we have done much work revamping refinery units to increase their outputs, or to make them more environmentally friendly. Often this has involved installing equipment on an operating refinery, ready for a quick piping-up operation when the refinery is shut down. Although welding may be acceptable during the shutdown, much of the pre-shutdown work is now done using flanged pipe sections which are made up off site, and then connected up on site without the use of any hot work.

5. Access to Confined Spaces

A number of operations become much more hazardous if the workers are obliged to work in a confined space with little chance of making a swift escape if an unexpected hazard suddenly appears.

If it is essential to carry out a hot-tap from scaffolding, then the level of safety can often be improved by using a larger working platform, with access ladders on opposite corners.

If the site erection of a cold box involves joining pipes together inside, then it makes this operation far less hazardous if the sides of the cold box can be designed to be installed last, after the piping is complete. In the past some cold boxes were designed so that the sides acted as supports for the contents of the box, and the sides had to be erected before the contents were installed.

6. Continuous Improvement

One area where we see opportunity for improvement in the future is in the area of design-supply-erect contracts. Here it is more difficult to have a close relationship with outside design engineers and additional effort is needed in this area. We also expect to see greater dividends from the use of intelligent flowsheets and intelligent models with their related databases.

(Intelligent flowsheets and models are those which have details of equipment sizes and process flows, temperatures and pressures stored electronically on the flowsheet or the model.)

CONCLUSIONS

Improving site safety by design is not inherently difficult. However, it does mean that a partnership has to be developed between the design engineers and the construction engineers. The result is that potential field hazards can be anticipated at the right time in the design process, and appropriate action can be taken well ahead of the site activities, to design the facility to avoid possible hazards to the construction workers.

This partnership between design engineers and construction engineers, and an increase in the ratio of pre-planned to unplanned work, can result in better quality in the completed plant, which is delivered on schedule, and within budget. The improvements to the project safety record speak for themselves.

DESIGN CRITERIA FOR ELECTRICAL SAFETY DURING THE CONSTRUCTION PHASE

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ABSTRACT

Electrical accidents are common on construction sites in Spain. We have worked in a field study on these risks. Many construction sites are studied. The object has been to identify the most usual existing defects in the provisional electrical plants on these sites.

Two main research lines are developed: Qualitative and Quantitative. Qualitative, includes aspects like external conditions and the placement point of the electric panels, the maintenance level of the plugs and sockets, Quantitative includes aspects like the stray current, the ground resistance etc.

After studying these data, we have established design guidelines for provisional electrical plants to reduce these kinds of accidents, and increase safety during different construction phase.

Keywords: Electrical, construction, safety

INTRODUCTION

This paper is based on a practical fieldwork carried out in the Technical University of Catalonia. The aim was to determinate the main aspects which can produce electrical accidents to the construction workers during different construction stages. We are also involved in establishing design guidelines based on the results obtained.

Two main research lines have been developed: qualitative and quantitative. Qualitative includes aspects like the external conditions and the placement point of the electric panels, the maintenance level of the plugs and sockets, Quantitative includes aspects like the current leakage, ground resistance, disconnection times,

All measurements we carry out monthly periodicity over 32 construction sites spread over all Catalonian region and all of them having different characteristics. Studies of the sites started during foundation stages. On Table 1, indicates the main characteristics of these construction sites.

Number of sites studied	32
Aim of the building:	Public and private sector
Number of workers:	10 - 100
Number of electrical panels on site:	5 - 12
Existence of safety manager on site:	Only in one
Range of site duration:	6 months to 2 years
Range of surfaces constructed:	600m² - 7000m²

Table 1: Main characteristics of construction sites studied

QUALITATIVE ASPECTS : RESULTS AND ANALYSIS

Most of the defects on temporary electrical systems are due to a deficient maintenance level. So the main focus on qualitative defects is: the electrical panels, the portable machines and the plugs and sockets maintenance.

Electrical panels

In electrical panels there are some frequent aspects which provoke a deficient level of safety. These are: absence of covers in the accessible parts of the panels that protect against atmospheric conditions, incorrect placement of these panels, in some cases next to water pipes, material storage hidden or with a very difficult access. Obviously all of them are in contradiction with the general principles of safety and cleanness on site.

Regular inspection of the maintenance level of electrical equipment is not carry out on construction sites. Very often an initial inspection of the correct performance of all electrical equipment coming from other sites is not carried out. A possible solution could be a complete inspection and if necessary, the renovation of the electric equipment before installing it on a new construction site.

Finally, in all contracts related with all construction sites studied preventive maintenance of the electrical equipment is not carried out. Figure 1 shows the evolution of the electrical panel's situation, before and after our study and the consequent recommendations.

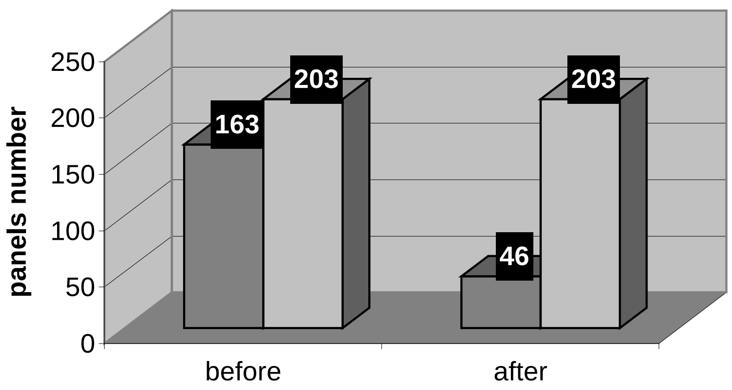

Figure 1. Evolution of non-satisfactory electric panels versus total studied

As a conclusion of this part it can be said that the bad maintenance level of these electrical systems originates most of the defects. An example of this is shown in Figure 2.

Portable electrical equipment and machinery

As far as the characteristics of portable electrical equipment and machinery are concerned , the majority do not an earthing system and most of the protection elements that the regulation establishes. For example in Figure 3 a portable circular saw without earthing and other protections can see seen.

In our case study, we have focused on the electrical aspects. As in electrical panels, we can observe that on first inspection the situation was extremely dangerous. After this inspection and based on our guidelines, the situation improved.

Figure 2. Example of non-satisfactory maintenance level of an electric panel

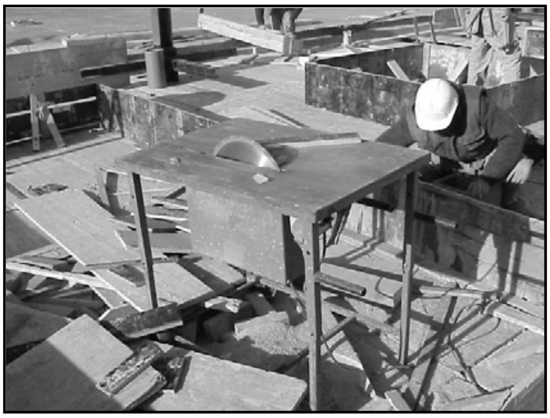

Figure 3: Portable circular saw

Figure 4 shows the above mentioned situation. In most of the cases the non-conformity is related with the absence of earthing connection systems; this situation is extremely dangerous for the worker.

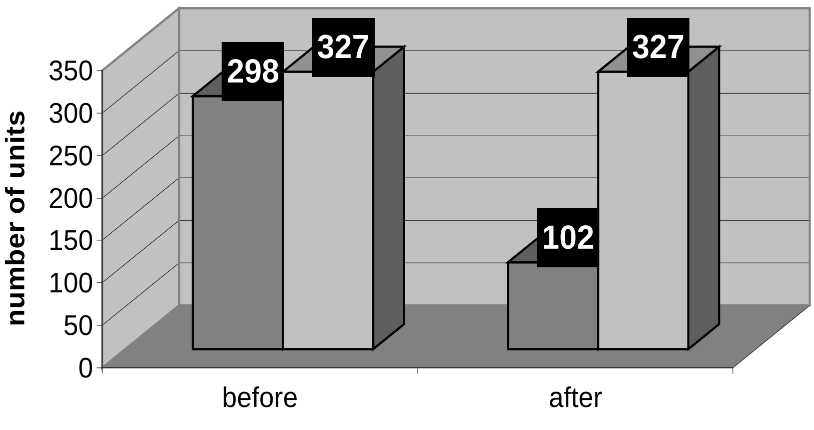

Figure 4. Evolution of portable electric equipment and machinery

Plugs and sockets

Most of these elements are in bad maintenance conditions. All of these are non-critical elements of the production process and their maintenance level is low. Usually they are revised and repaired when they do not work correctly or when they do not supply electrical power, and very often these reparations are deficient. The only aim is the temporary reparation in order to provide energy supply to machinery. This temporary reparation, at the end, is converted into a definitive reparations.
In Figure 5 a broken cable with a "temporary" connection is shown.

Figure 5. Broken cable with a "temporary" union

QUANTITATIVE ASPECTS: ANALYSIS AND RESULTS

Measurements of earthing resistance and disconnection time we carried out using a GOSSEN Electrical Tester according to DIN VDE 0100 German Standard.

Earthing systems
The main objective of grounding is to connect electrical equipment pieces to a protection system. With this, the electrical leakage currents are guided to the earth. It is very important to assure good protection connections to avoid accidental contact with the human body.

One accepts that the human body has resistance of 2000 Ohms, but this can be reduced to 1000 Ohms in wet ambient. According to Spanish Electrical Regulations (MIE-REBT) the maximum intensity that the human body can support with getting injured is 25 mA. Considering this data, the electric systems on site should not have higher than 24 V of voltage in wet ambient or 50 V of voltage in dry ambient. To achieve these voltage levels the earthing resistance of the protection system must be below 80 Ohms.

In this study we have measured more than 150 earthing resistances of the different sites. The main conclusion is that the resistance value is not constant. It is observed that the tendency of this earthing resistance changes as the project progresses. To demonstrate this, Figure 6 shows some measurements carry out on different sites during different months.

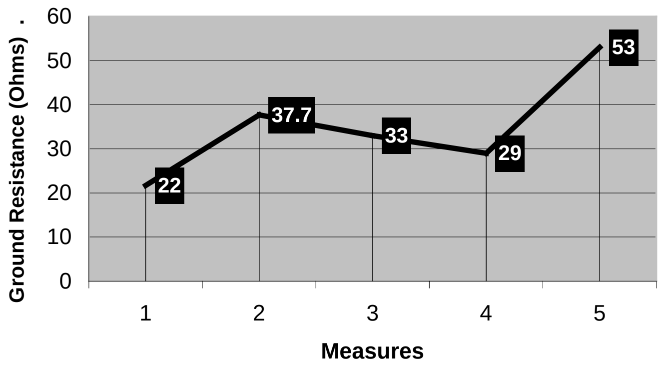

Figure 6. Evolution of ground resistance average

It is observed that when the building progressses, some environmental conditions of the area can change the earthing connections and their evolution can be dangerous. For this it is recommended that first the earthing resistance must be corrected and carry out periodical measurements to assure that the values are under correct levels.

As far as possible, the earthing must present the minimum ground resistance. In addition, must offer guarantees that the system has not the continuity broken. In addition, it must offer guarantee that the system has continuity. If this happens in whatever point of the earthing system, when on insulation defect of electrical equipment exists, then some of the metallic parts can be accidentally connected to usual voltage (220-240-380 V).

Finally, it could be equally dangerous for the worker if earthing system does not exist or it is badly connected or is in bad conditions.

Figure 7 shows an earthing connection in bad conditions as the site working progresses. This has been the most common defect on the sites studied.

Figure 7. Grounding connection not protected

Residual Current Device (RCD) sensibility and disconnection time analysis

As commented in last paragraph the earthing system is fundamental to protect workers. Together with this system it is necessary to install an element that detects leakage currents. This element is the RCD. When RCD detects a leakage current in a circuit, it cuts off the current. The main aspects on these RCD are the sensibility (leakage current value detected) and the disconnection time.

Obviously it is an ideal complement to earthing system and its absence leads to inefficiency. Figure 8 shows a typical short-circuit between parts of RCD

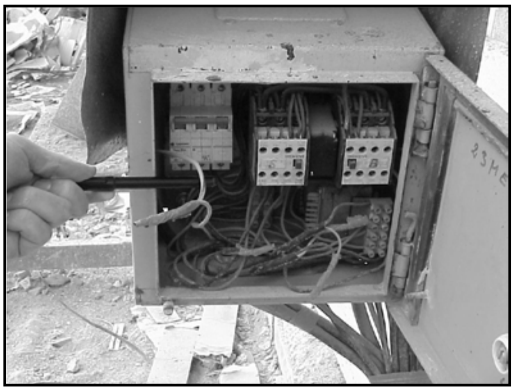

Figure 8. Real aspect of an electric panel of a crane.

Most of the studied construction sites have RCD with 300mA of sensibility. This value usually increases as this element ages because of the critical conditions of use that it has to support.

Figure 9 shows the evolution disconnection time of these RCD placed in the sites analysed. These measurements were carried out on different days fin different months.

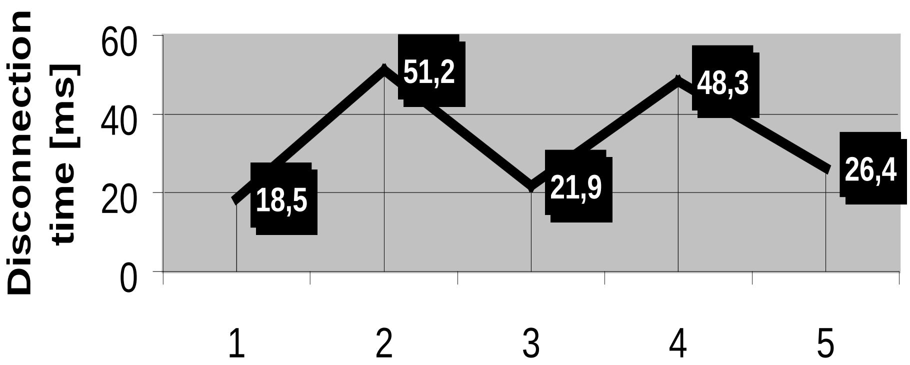

Figure 9. Evolution of disconnection time average on RCD's

The main conclusion derived from these results is that the values are depending on the days. For example the first value was measured on a day when it was snowing and the second measured on hot and warm day.

When disconnection time is high, the risk of important accidents for workers increases. In Figure 10 relation between the disconnection and contact intensity of electrical risk is shown. Area number 3 is the most critical, because there are high-damage accident situations for workers as they can suffer cardiac attacks if electrical shocks occur. Area number 2 has lower accident risk situations.

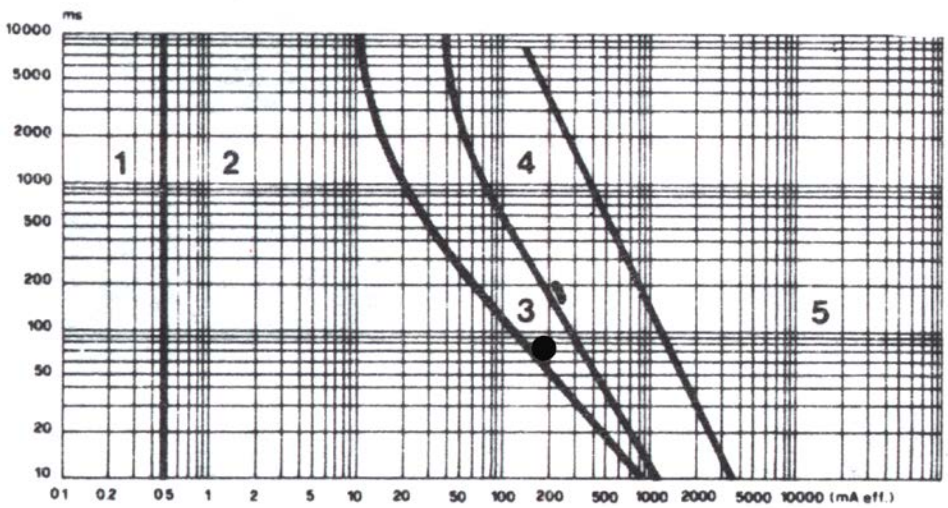

Figure 10. Contact intensity vs. disconnection time in RCD.

In our study, according to the 300 mA of RCD sensibility, the measures number 2 and 4 measurements are close to the black point. This means that there was a high risk of electrical accident on the construction site.

DESIGN GUIDELINES FOR TEMPORARY ELECTRICAL SYSTEMS

After these studies and analysis we are developed a guidelines to be used by the safety coordinators and the safety managers of the construction firms, when they are designing the preventive safety measures to be adopted on each site.
Some of these guidelines are mentioned on following paragraphs:

- **General recommendations**

1. For workers' safety, it is very important to carry out every month a revision procedure for all the electrical systems of the site.
2. To reduce electrical risks it is important that the design of the temporary systems on projects should be done under supervision of adequate technicians.
3. After each construction process, electrical equipment and machinery must be inspected in detail before reusing on a new site.

- **About electrical panels:**

1. To install them on accessible places
2. To install them over vertical supports
3. To install them at adequate distance from floors (>1,4 meters)
4. To fix them adequately over the support
5. To install electric panels on each floor

6. To provide an independent connection from each panel to the general supply
7. The maximum distance between the panel and the consumption point must be less than 25 meters
8. To install it under a solar protection and, preferably, under rain protection
9. To inspect visually these panels each month
10. To control and register the lifetime of these elements

- **Machinery, plugs and sockets.**

1. To install them on accessible places
2. To install them away from pipes water
3. To install distribution cables over the usual work area when it is possible
4. To avoid connections without plugs or sockets
5. To avoid distribution cables longer than 25 meters
6. To provide adequate weather protections for these elements
7. To maintain the machinery areas clean.
8. To design and provide adequate elements for the power to be supplied
9. To inspect visually these elements each month
10. To inspect periodically the disconnection time of the RCD
11. To inspect periodically the sensibility of the RCD
12. To inspect periodically the earthing resistance in each point of the system
13. To control and register the lifetime of these elements

CONCLUSIONS

In our study we are demonstrated that that the values of protection elements are depending on the days. So, the final and main conclusion derived from the results of this study is that when the building progresses, some environmental conditions of the area can change, and the earthing connections and RCD response times are variing, and this evolution and variability can be dangerous for the worker.

According the idea that preventive action is the better way to reduce risks on construction sites, our design guidelines could help to the technicians involved in this subject to introduce adequate preventive actions against electrical risks discovered on construction sites.

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DATA BASED MODEL FOR RISK EVALUATION IN BUILDING PROCESS

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ABSTRACT

A first aim of this paper is to show the difficulties that the designer has during the risk evaluation in building process. Most of the evaluation methods used in construction process don't consider the especial situations and needs of a risk evaluation for the building process.

Therefore, a risk evaluation method in building process must offer an estimation of the real number of accidents that could happen and their distribution along the different stages of the process to facilitate their prevention. In addition, we think that the risk evaluation method should account the cost of the damages expected in order to convince to the promoter and contractors to introduce an adequate safety level on site.

Keywords: Construction safety design, risk evaluation method, safety costs

INTRODUCTION

Considering the risks evaluation methods used in building industry, one founds some disadvantages. So, most of the used methods in Spain (Fine, 1975) have a lack of information about the risks. In addition, the Safety documents are redacted during design stage. At this moment, it is very important to know the probability that the accident happens and the usual methods don't supply this information.

We also try to apply methods widely used in other kinds of industry, like chemical or process plants (Less, 1980; AICE, 1985; FIOH, 1989). Some of the methods considered in our study have been:

Method	Objective	Application	Results	In Building
PHA	Initial identification of risks to save futures costs	Design	List of risks and a qualitative description.	General identification of risks in **Safety Plan** definition. It will help us to design the safety protections.
HRA	Initial identification of risks based in past events	Design	List of risks and a qualitative description.	
What if...?	Quality identification of risks supposing several situations.	Design and in existing installations	List of risks and a qualitative description.	
JSA	Analysis of working procedures.	Analyse operations	List of critical operations.	
FMEA & FMECA	Event and consequences ident. that can cause accidents	Project engineering and existing installations	List of risks and safety measures to avoid them.	
Event tree risk analysis	Identification of the chain of events that drive to the accident.	Project engineering and existing installations	Group of events that drive to the accident. Probability estimation	Not applicable in building process due to the lack of data information. Don't exist database about building accidents in Spain.
Human Reliability	Very related with event tree risk analysis	Project engineering and existing installations	The same results as Event tree but considering human activity.	
Working conditions analysis	Analysis of the workplace (temperatures, distances, weights, positions,.....)	Design the workplace characteristics.	Definition of the workplace operations.	In building industry, we can't talk about fixed and organised workplaces.

Figure 1: Study methods

As we can see, it does not exist a method that solve the problems of the poor risks evaluation carried out in the building process, or they can't be applied in the building industry. Therefore, we have decided to define a new method of risks evaluation.

MODEL PROPOSED FOR THE LABOUR RISK EVALUATION ON CONSTRUCTION

We have developed a model to estimate the expected distribution of risks for each stage of the building process. To estimate this distribution we have collected statistic data from the Spanish Government. Then we have analysed them in order to make it applicable in later design process decisions and documentation.

This risk estimation will be influenced by some essential factors that determine the probability that the risk could be materialised. These factors considered in the evaluation model are the size of the building company, the experience of the workers who are involved into the process and the kind of contract between the worker and the contractor firm.

Moreover, to evaluate the accident severity level for the firm, we have defined a model to account the expected costs in case that the accident happens. It will be useful to demonstrate to the contractor and promoter that the prevention measures have an effective economic value.

This model permits to the designer to determinate the right level of safety in each building project according the real design carried out. In addition, it provides the definition of the most dangerous activities, and it allows putting more emphasis in the adequate workers protection. So, the applicability is clear into design offices and into the safety co-ordination works during design phase.

Results of this model are:

- the estimated number of accidents that could happen during the building process. This model is based in statistic data of the own building industry. These data usually are published by each national government agency or they can be internal of each contractor firm. In this last case, results of the model will be more accurate and definitely related to each individual building project.
- the analysis of each stage individually, quantifying the accidents that could happen. This quantification must be done for each kind of risk identified. Therefore, the designer could decide for each risk the most suitable safety protection depending of the estimated number of accidents, and the expected cost.

Estimation of the expected accidents number on site.

The evaluation of risks in the building process depends on three key factors, at least:

- We know that the inexperienced workers have more possibilities to suffer an accident. Therefore, our risk evaluation must consider the characteristics of the workers involved in each building process.
- Second aspect is the contractor size. The contractor firms with less than 10 workers suffer more accidents than the big ones (Lorent, 1993). Our model ought to consider this aspect, too.
- Is also commonly recognised that workers with strong labour relation with their firm are less affected by accidents that other temporary workers. This aspect also must be included in the model.

Our model starts considering the current Incidence Index in percentage of accidents in the building industry. Over this percentage, we will apply the three key factors already mentioned as three different coefficients: the building company size (T), the worker experience (A) and the kind of worker contract (C).

Then the number of accidents that could happen in each building site is depending of the next variables:

$$\text{Number of accidents } (N) \cong f\,\{I.I., T, A, C\}$$

Now, we have to add the number of workers who plays in the building process and its expected time duration. Finally, we show the final equation:

$$N = D \cdot I.I. \cdot \Sigma (W_i \cdot T_i \cdot A_i \cdot C_i)$$

Where:

i =	Worker Class with same associated factors
N =	Number of estimated accidents
D =	Length of the building process in years.
W =	Number of workers involved in the building process.
I.I. =	Incidence Index (data from national agency or internal to each firm).
T =	Coefficient of building company size.
A =	Coefficient of workers experience.
C =	Coefficient of worker contract class.

The coefficient values are defined on Table 1.

SIZE (workers)	COEF (T)
1 to 9	2
10 to 49	1
50 to 100	0,75
101 to 249	0,5
More than 500	0,25

EXPERIENCE (years)	COEF (A)
Less than 1	3
1 to 3	1
3 to 10	0,6
More than 10	0,6

KIND OF CONTRACT	COEF (C)
Staff permanent	0,25
Temporary	1

Table 1. Coefficients of key factors.

These coefficient values have been defined studying and analysing the importance of each class in the statistic data of the Spanish building industry. These data are published by the Spanish Labour Ministry and completed by other organisations involved in risk prevention on construction works.

At this moment, we have estimated the number of accidents that could happen during one building process. Now we want to define their distribution along the different stages of the process.

1.2 Estimation of accidents distribution during the building process

The identification of the stages more dangerous and the identification of the more frequent kind of accidents are the aims of this part of the model.

From the statistic data of the Spanish Labour Ministry, we can see that the general distribution of accidents in building industry is:

- Light accidents: 98,16 % of the total accidents
- Serious accidents and fatalities: 1,74 % of the total accidents

In addition to these general data, we have to take in account the distribution of accidents in Spanish building industry and considering the different stages of the site. This distribution is shown on Table 2.

One could apply it over the estimation of the number of accidents by each phase and by identified risk.

To do it, one can consider the following situation: How many light (or serious) accidents of the X kind are expected to occur in the stage Y?

$$\textit{Number of accidents}_{(light:X:Y)} = N \cdot P_{(light)} \cdot P_{(stage\ Y\ and\ light)} \cdot P_{(satge\ Y,\ kind\ X\ and\ light)}$$

Where:

N = total number of accidents

$P_{(light)}$ = probability that that the accident will be light (or serious).

$P_{(stage\ Y\ and\ light)}$ = probability that the light accident happens in the Y stage.

$P_{(satge\ Y,\ kind\ X\ and\ light)}$ = probability that the light accident will be of the X kind in Y stage.

Finally, as a summary of the process model, we show in Figure 2 the complete procedure.

STAGES and RISKS	LIGHT ACCIDENTS		SERIOUS ACCIDENTS & FATALITIES	
DEMOLITION	**3,07%**		**4%**	
Falling objects overhang		14,38%		40%
Falls of people at same level		7,71%		27%
Running over or kick by vehicle		2,23%		9%
GROUND MOVEMENT	**16%**		**11,01%**	
Falling objects overhang		35%		14,05%
Parts projection		9%		33,06%
Electrical contacts		9%		2,24%
Falls of people at different level		20%		6,38%
Running over or kick by vehicle		14%		3,88%
Falls of people at same level		4%		8,26%
FOUNDATIONS	**3%**		**3,45%**	
Falls of people at different level		21%		4,01%
Kick and cuts with tools and objects		18%		35,11%
Object falling in use		13%		15,96%
Caught between objects		15%		8,21%
Falls of people at same level		9%		11,13%
Running over or kick by vehicle		12%		1,99%
STRUCTURES	**34%**		**39%**	
Falls of people at different level		47%		8,99%
Object falling in use		10%		12,30%
Kick and cuts with tools and objects		14%		27,35%
Falls of people at same level		4%		4,95%
Footstep over objects		4%		13,04%
Parts projection		2%		4,41%
CLOSURES & ROOFING	**16%**		**18,84%**	
Person falling at different level		71%		21,05%
Object falling in use		7%		13,35%
Person falling at same level		6%		11,52%
Kick and cuts with tools/objects		2%		6,06%
FINISHES & INSTALLATIONS	**27%**		**31,63%**	
Falls of people at different level		36%		6,74%
Object falling in use		13%		15,66%
Falls of people at same level		8%		9,70%
Caught between objects		9%		4,83%
Parts projection		3%		6,47%
Kick and cuts with tools and objects		8%		15,30%
	100%		**100%**	

Table 2. General distribution of accidents in Spanish building industry

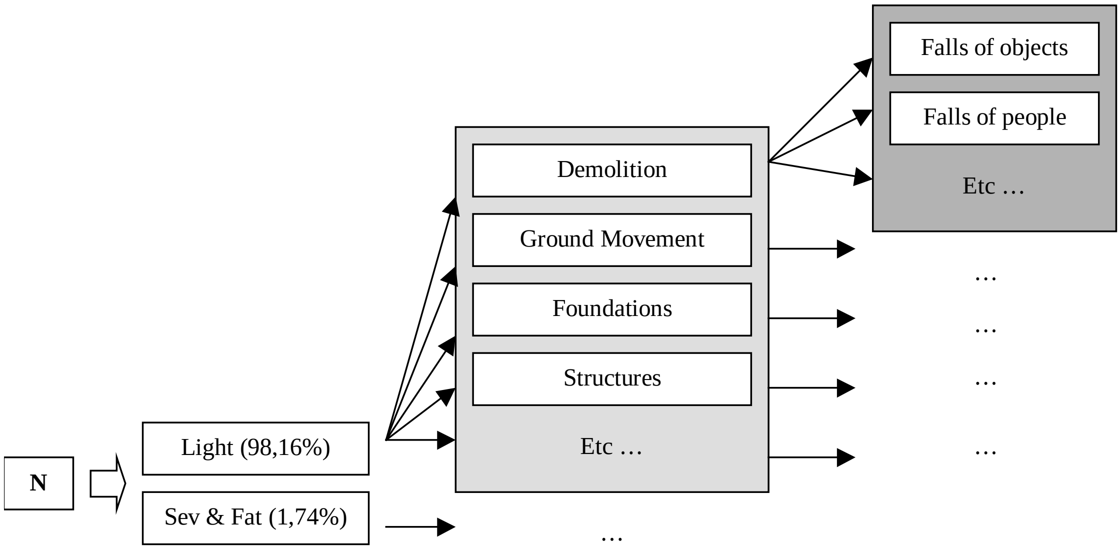

Figure 2. Complete process of the model.

Method to estimate the non-safety costs on particular sites.

As we have explained before, this method of risks evaluation also can be used to consider the expected level of costs of the estimated number of accidents. This is very important because we could measure the risk, or the severity of the damage in objective units, that we can apply in all cases.

The objective of accounting costs is double. On one hand, we could identify the more dangerous stage, and then we could put more efforts to avoid these accidents. In the other hand, we can do a cost-benefit analysis among the safety measures and the expected costs of the accidents.

We have considered a classical division between costs (Bird, E. 1975). According this, we are applied it over building industry. The considered costs have been:

DIRECT COSTS: Usually easy to account.	
Working day that accident happens	50% from the work's day
Quotation to health insurance	In Spain 31,31 % from the salary
Complement of the paid leave	In Spain 25% from the salary
INDIRECT COSTS: Difficult to account. Often, they are associated to a productivity reduction. These kinds of costs are always higher than the direct ones.	
Cost of worker replacement	100 % of salary and quotation to health insurance.
Cost of new worker equipment	1 hard hat, 1 working suit and a pair of boots
Cost of accident research and assistance (INSH NTP 273, 1991):	Assistant: 6 hours of other workers Research: 8 hours of the safety manager

Some costs are accounted only for the day that the accident happens. The concepts for these costs are:

- Working day that accident happens.
- Cost of new worker equipment.
- Cost of accident research and assistance (INSH NTP 273, 1991)

The other costs will be applied all the days of convalescence:

- Quotation to health insurance
- Complement of the paid leave
- Cost of worker replacement

Both kind of costs define the total cost of the accident for the project. Obviously, the final affectation of these costs will be depending of the contractual terms among the project participants.

We also have to remark that in this cost analysis we have considered only the light and serious accidents. Costs of fatalities usually depend of liabilities between process participants and sometimes are consequence of trials.

APPLICATION AND DISCUSSION OF THE MODEL

In order to make discussion, we present the application of this method to one building process with the next summarised characteristics:

- Length of this building process: 1,5 years.
- I.I. applied (Spanish building industry): 16,4 % (1997 data).
- Number of people working at the same time: 25 workers.
- Total number of workers: 75 workers.
- Average length of convalescence in light accidents (MTAS, 1999): 21,88 days.
- Average length of convalescence in grave accidents (MTAS, 1999): 83,12 days.
- In case of accident, the company replaces the worker.
- Cost projected for safety protection (individual and collective): 29.393 €.

We have considered the characteristics of the workers that will define the key factors of the accidents. The summary of characteristics is on Table 3.
The final estimation of accidents will be:

$$N = D \cdot I.I. \cdot \Sigma (W_i \cdot T_i \cdot A_i \cdot C_i) = 21,79$$

6 Workers	
A= More than 3 years	A=0,6
T= More than 50 workers	T =1
C= Permanent	C =0,25

10 Workers	
A= Less than 1 year	A=3
T= 5 workers	T=2
C= Temporary	C =1

6 Workers	
A= 2 years	A=1
T= 10 workers	T=2
C= Temporary	C =1

3 Workers	
A= Less than 1 year	A=3
T= Less than 10 workers	T=2
C= Temporary	C =1

Table 3. Summary of workers characteristics

The distribution in the different stages of this result is shown on Table 4. These data must be understood just as statistic average data.

STAGES	Number of light accidents	Number of serious accidents
Ground movement	2,4314	0,0662
Foundations	0,7613	0,0124
Structure	8,6146	0,1408
Closures & Roofing	2,6142	0,0662
Finishes & Installations	6,9859	0,1118
Total of accidents	**21,4074**	**0,3974**

Table 4. Distribution of accidents on the case study.

With these data, the non-safety costs estimated by the contractor firms during the execution stages are on Table 5. These are due the total of accidents expected during these stages.

	Light accidents	Serious accidents	Total accidents
Direct Costs (€)	11.270	774	12.044
Indirect Costs (€)	28.158	1.836	29.994
Total Costs (€)	39.428	2.610	42.038
Percentages	93,79%	6,21%	100%

Table 5. Non-safety costs on the case study.

Usually on sites, the accident happens when the protection measure fails or they don't exist. Then we can assimilate this safety level to the absence of preventive measures (100 % risk).

	With usual prevention	Effective Collectives & Individual Protections
Risk level in (€)	42.038 (100 %)	**8.408 (20 %)**
Safety protection costs (€)	---	**29.393**
Final cost (€)	42.038 €	**37.801 €**

Table 6. Costs comparison on the case study.

Finally, we will consider the reduction of the risk level that supposes the application of the adequate and efficient safety protections. At this moment, we can estimate the total cost of the building process including the residuary non-safety costs and the costs of these projected safety protections. To make this analysis we have considered the reduction effect due to the safety protections according to practical data from some building process carried out by one building company (Fidalgo, 1998).
On Table 6 we show this comparative analysis.

As we can see, for the building contractor firms is better to introduce a very efficient safety protections level. If they do not use this protection level, they can suffer the total cost estimated for the accidents.

CONCLUSIONS

First of all, we have to remember the worse situation in accidents if we compare with other industries. One big reason of this situation is owing to the difficulties to evaluate and control the risks in building process. Moreover, we think that this fact is due to the lack of useful information about the existing accidents.

In addition, the classical evaluation of risks in building process does not offer useful information about these risks. And usually the designer does not have enough resources to decide the suitable safety protection, moreover from his own experience.
Our model offers to the designer useful information about the number of accidents that could happen on site and about the expected costs provoked by these accidents. This will be very useful to design the safety protection because we can determine the most dangerous operations and stages of the building process, and then we can assign more efforts and resources to the safety level of these stages.

This model could help to plan the inversion in safety not only related to safety protection defined by law. Moreover, we can plan a long-dated strategy to reduce the number of accidents of a building company, and in a short-term considering the circumstances of a focused building process.

Finally, we have detected some points that this method should consider but actually is difficult to introduce these into it because doesn't exist enough information in the building industry. These points of improvement would be to consider other building attributes as kind of materials used, surface of the site, the height of the building, etc.
And the most important thing to consider in a new model for evaluating risks should be that the designers don't need universal methods. They need a method based and focused to the procedures and statistic data of the own building industry.

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INDUSTRIAL DESIGN AT THE SERVICE OF SAFETY AND HEALTH

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ABSTRACT

"More than half of work accidents are due to conception faults", or so most of the European or national preparatory legislation texts state. But design influences the construction sector not only during the conception phase. There are numerous other designers who come far earlier than architects and engineers for building construction and public works. Among them are the industrial designers who significantly influence the production of tools and building site equipment.

It is well known today that the ergonomic quality of tools and equipment for the construction phase often causes work-related diseases that develop insidiously over many years. They diminish progressively the worker's capacity to accomplish daily tasks until partial or total work incapacity, often irreversible. During the evolution of this yet-undeclared disability the worker is involuntarily placed in a situation harmful to health. In the same time, the worker's gestures and reflexes are being weakened and generate risks dangerous not only for the worker, but also for work companions and for the progress of the construction phase.

Thus the conception of tools and equipment becomes an important determinant for safety and health of participants on the building site.

A vast research area is still unexplored in the field of industrial design and we should analyse the reasons for this. The lack of positive and rapid evolution in this area is indeed amazing, when we think of the important market open to these kinds of products.

The difficulties in achieving progress in this field may be due to several factors: a professional education that is still heavily bound to traditional practices; the contractors' and workers' reticence in changing their practice habits; and the fear of innovation in the conception and production of building materials.

Key words: industrial design, safety, health, ergonomics

INTRODUCTION

The sixth preamble of the European Directive 92/57/EEC of 24 June 1992 on the implementation of minimum safety and health requirements at temporary or mobile construction sites states the following:

"Whereas unsatisfactory architectural and/or organisational options or poor planning of the works at the project preparation stage have played a role in more than half of the occupational accidents occurring on construction sites in the Community;…"

The statistics published by the European Community Services show that falling from height causes 35% of fatal work accidents in construction and that this can be diminished mostly through design [1].

The French word *"conception"* and the English *"design"* do not have exactly the same meaning. "Design" contains a connotation of "plan" or "intention", and is more appropriate for drawing, for graphic studies, like the architecture project.

It is surely one of the reasons which led to a negative reaction from the architects' representative bodies, both on European level and on each Member State national level when it came to transposing the European Directive and the application means of this important legislation to the national level.

Architects had forgotten that in most European countries, as well as in the whole world, the majority of buildings are conceived and realised without the intervention of authorised or liable architects.

Nowadays, mentalities have largely evolved and a lot of architects are practising as "co-ordinators for safety and health matters on temporary or mobile construction sites".

Alas, in what concerns the industrial designers, it seems that they are not yet aware of the issues concerning safety and health in relation to the use of tools in the construction industry.

Anyway, statistics at European level show that *"60% of fatal accidents on building sites have causes generated by a choice made before starting the work"* (DG V. F.5., 1991)

"But conception/design influences the construction sector not only during the conception stage. Numerous other designers act far earlier than the architecture and engineering offices for buildings and public works construction. Among them the industrial designers, who deeply influence the production of tools and building site equipment."

Industrial design represents the esthetical and technological research based on the industrial production of objects with attractive and functional forms. This research is heavily bounded on functional level to **ergonomics**, which is the study of working conditions aiming to best adapt the professional environment, the tools or the engines to the human being.

[1] In *« From Drawing Board to Building Site. Working Conditions, Quality, Economic Performance »*, European Foundation for the Improvement of Living and Working Conditions, HMSO London, 1991, page 30

"The whole history of tools, the way they have been modified along centuries in order to follow up the new technologies by better adapting to the human being's features, is in fact the history of ergonomics which ignores itself.

Ergonomics represents the ensemble of scientific and technical knowledge concerning the human being, necessary for designing tools, equipment and other devices, which guarantee a maximum of comfort, safety and efficiency.

Ergonomics is thus a multi-disciplinary science. It appeals to:

- *philosophy and anthropology*
- *experimental psychology*
- *social psychology*
- *sociology*
- *engineering science*
- *economy*
- *medical science of work*
- *work organisation science"*[2]

Taking into account the working environment means paying a particular attention to several factors, like:

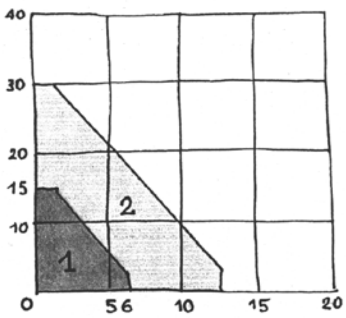
- Noise: generated by engines, machines, shocks, whistling, etc. Acoustical corrections of harmful noises consist in creating more or less voluminous envelopes to isolate or absorb harmful sounds, or in working on the amplitude of the uttered sound-waves since their source.
- Vibrations and shocks: rectified by using "silenblocks" and damping layers
- Dust and volatile products: in the air, sometimes invisible and odourless, but which may cause serious injures to the human body; smoke and hydrocarbon, etc.
- Lighting: natural or artificial, too high or too low, direct or indirect, whose defaults may lead to risks of accidents or illnesses.
- Dimensions of the working position: which determine the conditions of a necessary comfort and the stress caused by an extended promiscuity.
- Work organisation: its rhythm, its duration, individual or collective, with visual contact with other workers, etc.
- In general: heat, cold, bad weather [3]

[2] CEERI (Centre d'Etudes Ergonomiques et de Recherche Industrielles), Bruxelles (B), « *Analyse du poste de travail* », prof. VAN DAMME

The analyse of activities and gestures during the work process concerns also other important factors, as:

- Handling (See Figure 1)
- Working position, its stability
- Repetitive movements
- Weight and room occupied by objects to handle, their luminosity or colour [4]
- Commands of machines and their security systems
- Individual protection depending on risk factors

Unit-mass (kg)



Tonnage / day

1- acceptable area (women)
2- acceptable area (men)

Figure 1: Diagram concerning the manual handling of loads [5]

Ergonomics brings up different possibilities of intervention, like:

- Conception ergonomics
- Correction ergonomics
- Ergonomics for means of production
- Product ergonomics
- Ergonomics for the worker's protection

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[3] Besides the injures already mentioned, one may ask oneself on injures still little known related to the effects of magnetical fields and of certain trivialised waves. Not to mention the risks to safety and health caused by drugs, alcohol, tobacco, …

[4] As a joke, I may say that my usual wine supplier from the « Côte du Rhône » vineyard has informed me that starting this year wine will not be sent anymore in 33 litres cubical packings, but in 20 liters packing. This happens as a result of a claim from the vineyard workers' trade union… What should one then say about the construction workers who must handle 50 kg cement packs without lifting devices ?

[5] source : *« Comment concevoir et aménager des postes de travail »*, Dossier INRS, http://www.inrs.fr

"It is well known today that the lack of ergonomic quality of tools and equipment used for the construction stage often causes work diseases that develop insidiously during many years. They diminish progressively the worker's capacity to accomplish the daily tasks until partial or total work incapacity, often irreversible. During the evolution of this not yet-declared handicap, the worker places himself involuntarily in a harmful situation to his health. In the same time, the worker's gestures and reflexes are being weakened and generate dangerous risks not only for himself but also for his work companions and for the progress of the execution stage."

On the occasion of the International Conference on "Safety Co-ordination and Quality in Construction" organised by CIB in Milan in June 1999, I was very impressed by the original remarks of Professor Wim Schaefer from the Eindhoven University of Technology (NL). The meaning of his intervention was the following:

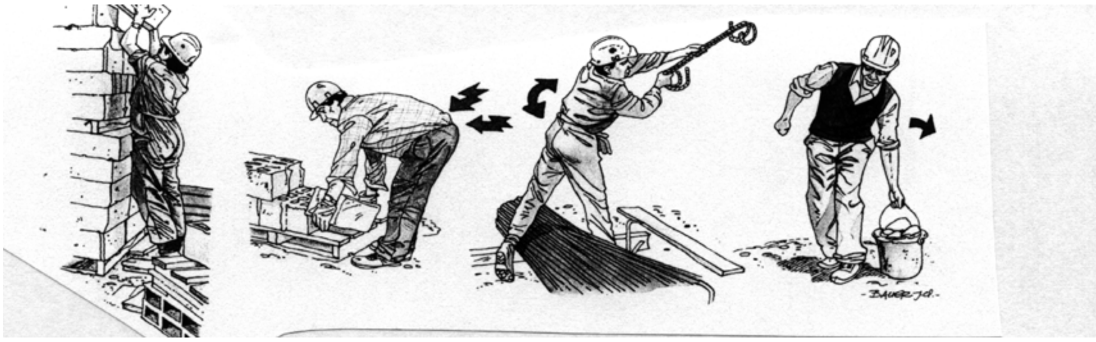
One says that in The Netherlands we are really expert in buildings painting work. Nevertheless, there are still numerous situations where one can see a house-painter perched on a stepladder in a very uncomfortable position, supporting a 3,5 kg pot of paint suspended on a cutting iron-wire arched handle, with the right arm stretched holding in his hand a brush for spreading the paint on the walls or ceiling. This lasts for 6-7 hours per day, during several years. It is not astonishing that this worker will rapidly suffer from tendinitis and more and more acute elongation which will cause not only an unavoidable efficiency loss, but will also diminish the speed of protection and safety reflexes in case of accident. In this ordinary study-case, what should be revised is not only the stepladder or the paint packaging or the painting brush. It is the whole working position that should be revised.[6] Which is very difficult, because it touches the house painter's quasi-symbolic working attitude, and because there is not much hesitation when choosing between a tendinitis supported by the social security and a 5% extra cost per square meter of surface to be painted.

I had summarised Professor Schaefer's intervention in my report of activity at that time as follows:

" … The cultural approach of safety in the construction sector in The Netherlands is a very interesting way, as it has already been demonstrated that laws and provisions are applied in practice only when they really respond to measures which are able to be assimilated among the natural reflexes of the human being. Too numerous traditions and habits in the execution work cause losses of efficacy which lead to "foreseeable" risks."

Numerous research related to work medicine in several countries and especially, the prevention campaigns initiated by INRS (Institut National de Recherche et de Sécurité, France) or by CNAC (Comité National d'Action pour la Sécurité et l'Hygiène dans la Construction, Belgium) emphasise injures to health on construction sites. Thus, repetitive stretching, flexing, rotation or bending may injure the backbone (lumbago, sciatica, discal rupture (hernia). Furthermore, inadequate gestures or working positions may cause epicondylitis and inflammation of tendons or hygroma (housemaid's knee.). The studies emphasise the repetitive character of the inadequate working conditions, which may cause tiredness, wear and premature ageing.

[6] Not to speak about the additional dangers related to work at height or in staircases …



Stretching *Bending* *Rotation* *Inclining*

Risk of irreversible lumbar injures ➔ **REPETITION = DANGER**

Figure 2 Injures of the backbone: lumbago, sciatica, discal hernia [7]

It may not be useless to remind that handling is an important cause of accidents or working injures: 3 to 10% of occupational accidents are related to backaches at 70-80% of workers in the construction sector.

"Thus the conception of tools and equipment becomes determinant for the safety and health of the participants at the construction site. Numerous examples of usual execution of construction work show the origins of different slow and insidious pathologies and malformations. These exist since many years because of the traditional craft models used in the production of working tools, which impose themselves to the user rather than vice versa, as shown in contemporary ergonomic studies."

Some well-known manufacturers from the field of tools have carried out studies of this kind. Thus, for instance, firms like STANLEY in the United Kingdom or HUSQVARNA (specialised in manual motorised tools) and SANDVICK in Sweden.

A study has actually been undertaken by INRS called *"Project instruction study: Ergonomic design of manual tools (CEROM)"* [8]. It may be summarised as follows:

"Integrating prevention since the conception stage represents a pertinent perspective towards the control of professional risks. Nevertheless, the efficiency of this approach is more and more subordinated to the association of knowledge coming from different technical disciplines and ergonomics. The conception of surer and less dangerous manual tools (like hammers, portable engines, computer keyboards, etc.) is naturally placed in this perspective. In other respects, the important increase of muscular-skeletal troubles (TMS, trouble musculo-squelettique) since several years gives a good account of conducting an important effort towards the control of this risk. The design of new ergonomic tools is a good mean…"

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[7] source : INRS booklet *« Prévention des accidents de manipulation et de transport dans le bâtiment et les travaux publics »*, doc. ED 719

[8] source : http://www.inrs.fr/recherche/etudes/A.8_2.013.html

A vast research area is still unexplored in the field of industrial design and we should analyse the reasons of such lateness. The lack of positive and rapid evolution in this area is indeed amazing, when thinking of the important market open to these kinds of products. Thus, for instance, we may quote the Polish example of an important contract for building prefabricated houses conceived as a "kit" to be assembled. The contract was awarded to an American firm whose success was due in particular to the integrated supplying of an ergonomic set tools allowing an easy and rapid assembly and the guarantee of safety and health for the workers involved. It should be added to this example that the same American prefabrication firm was also supplying the nails, staples, bolts, cartridges and other indispensable accessories… But this is another story.

"The difficulties in achieving progress in this field may reside in several facts: a professional education still heavily bound to traditional practices, the contractors' and workers' reticence in changing their practice habits, the fear of innovation in the conception and production of building materials…"

In fact, one of the major factors for the evolution of this field is surely the unlimited price competition. As a matter of fact, all research requires important investments and the "design" ergonomic tools cost more than the traditional ones, which leads to non-competitive prices of procurements awarded on the basis of the lowest cost.

When assessing the LCC (Life Cycle Cost) of buildings it should be thus useful to integrate not only the incidence of the global impact on the environment, but also the incidence of prevention measures in favour of safety and health of all participants.

The whole question is about generating a deep cultural revolution, which will grow towards the seeking for a generalised well being or better being.

This may be a very realistic utopia, after all.

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ELIMINATION OF UTILITY LINE CUTS ON A HIGHWAY PROJECT USING SUBSURFACE UTILITY ENGINEERING

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ABSTRACT

The cost of worker's compensation, personal injury, and builders risk insurance is a considerable expense for which a contractor must account. Currently, most contractors attempt to control the cost of worker's compensation insurance by keeping their accident rate low. Recent studies show that two of the top accident concerns by contractors are cutting utility lines and the accidents that result. However, an emerging branch of engineering called subsurface utility engineering (SUE) is being employed to eliminate the risk of accidents caused by utility line cuts. The concepts and practice of SUE have been developed and refined over many years, but basically were systematically put into professional practice in the 1980s. Several states have programs whereby the state departments of transportation (DOT) contract with SUE providers to map utilities on their projects in the design phase to eliminate the presence of unknown utility lines. A recent research project was conducted that evaluated SUE for the Federal Highway Administration (FHWA). Seventy-four projects were studied for the report and this paper that involved a mixture of Interstate, Arterial, and Collector Roads in urban, suburban, and rural settings. DOT project managers and engineers, utility owners, constructors, designers, insurance carriers, and subsurface utility engineers were interviewed to determine the value of SUE as a damage prevention technique. No accidents involving utility line cuts were reported on these projects. This paper focused on the benefits of the damage prevention aspects of SUE. The results of these interviews, and the examination of other damage prevention reports formed the basis of the results and conclusion portion of the paper.

Keywords: ASCE utility standard, damage prevention, FHWA SUE report, subsurface utility engineering, sue design process

INTRODUCTION

Damage to underground utility lines continues to be one of the major problems for the US construction industry. According to the American Institute of Constructors (AIC), the third most important crisis for contractors is damage to utility lines. (Reid, 1999) Hence, the proper knowledge of all existing utility lines and their location is an integral part to a successful construction project. (Lew, 2000) Not knowing utility line locations on a construction project may result in delays, or worse, in accidents. Many reasons can be given for the existence of improper subsurface information and frequency of utility line cuts. Some of these reasons are: inaccurate locations shown on project plans, poor field coordination between utility companies and contractors, and inaccurate locating and marking of existing utilities during construction. Subsurface Utility Engineering (SUE) is an emerging technology that has been shown to be a proven solution to the problem of underground accidents. The idea behind SUE is to discover and accurately portray utilities and disseminate the information prior to the project construction so that conflicts and disasters can be minimized. One major area to attempt to minimize is the relocation of utility lines. About half of all federal-aid highway and bridge projects involved the relocation of utilities during fiscal years 1997-98. (USGAO, 1999)

SUE 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. These technologies encompass surface geophysics, surveying techniques, mapping techniques, CADD/GIS systems, etc. Rather than disclaiming responsibility for existing utility information, SUE engineers certify utility information in accordance with a standard classification scheme that allows a cleaner allocation of risk among the project owner, project engineer, utility owner, and constructor.

FHWA REPORT PURDUE STUDY

The US Federal Highway Administration (FHWA) has been promoting the use of SUE since 1987 as a means to save costs on highway construction projects. The FHWA commissioned Purdue University to study the cost savings from four state departments of transportation (DOT) that routinely utilize quality levels while producing contract drawings. DOT project managers, utility owners, constructors, and designers were interviewed. Virginia, North Carolina, and Ohio were initially selected to be part of this study. Texas was added due to their rapidly growing SUE program. Studied in detail were 71 projects randomly selected from a list of projects in the four states that utilized SUE including Interstate, Arterial, and Collector Roads in urban, suburban, and rural settings. Although the data is extremely limited, included in the report also were Wyoming, Puerto Rico, and Oregon to whom the FHWA had provided seed money to try SUE on a selected project each.

Two broad categories of savings emerged: quantifiable savings and qualitative savings. A total of $4.62 for every $1.00 spent on SUE was quantified. Qualitative savings were non-measurable, but it is clear that those savings are also significant. Only three projects returned less in savings than expenditures. This leads to the conclusion that SUE is a viable technologic practice that reduces project costs related to the risks associated with existing subsurface utilities and should be used in a systemic manner. (Lew, 2000) One recurring factor that emerged from the study was that a major benefit of SUE is increased safety. Utility line locations are known and thus the risk of contacting them is greatly reduced. Hitting underground utility lines is a major problem in the construction industry and occurs with disturbing regularity. Proper knowledge of the location of utilities can significantly reduce or eliminate the hazard of hitting an underground utility.

Following are brief discussions of the damage prevention benefits of the states included in the FHWA report.

Typical SUE Demonstration Project in Wyoming

In Wyoming, the FHWA demonstration project went well. Abandoned utility lines, like old gas lines, would have been a problem on the project. SUE was able to identify the abandoned utility lines and safely deal with them during construction so that no accidents or delays were encountered. In a recent on-going project in Wyoming, a decision had been made not to use SUE which resulted in causing a one-year delay in the $10 million project. The initial surface survey and markings by affected utilities (contract locators) led to the belief that the area was clear of potential subsurface conflicts; however, this was not true, and before the contract was bid, major conflicts were discovered. That initial surface survey indicated a single phone line when, instead, there was a major fiber-optic duct. It has been determined that the duct must be relocated to accommodate the storm sewer that cannot be redesigned due to terrain and property issues. (David Bryden, personal communication, March 00) Due to incidents like these and the awareness that there is now a better process, controlled by professionals, SUE is rapidly becoming accepted as a good, beneficial process that should be incorporated into the design phase of a project.

Damage prevention from the FHWA Report for Virginia, North Carolina, Ohio and Texas

The damage prevention benefits of SUE for Virginia, North Carolina, Ohio, and Texas are discussed with summary comments from key personnel. In **Virginia**, SUE is used for utility evaluation early in the design stage. On the 9 projects included in the report, no major cuts or conflict delays were encountered. (Wayne Brooks, personal communication, February 2000) For **North Carolina**, Table 1 summarizes the damage prevention benefits of SUE. In **Ohio**, 14 projects were included in the FHWA report. In the first 5 projects, two cuts of utility lines occurred: The first was a new, relocated line that was not SUE provided; the second was an affected utility's contractor who did not look at the project's plan before directional boring. *SUE is effective in damage prevention and should be used in the design stages of the project*, reported James McGrath of ODOT. (personal communication, March 2000) The next five Ohio projects reported no contact with any utilities on the projects. Jeff Diosi of ODOT (personal communication, March 2000) stated that as soon as a project identifies that there might be potential conflicts, a SUE provider is employed, and ideally this happens in the planning stage, prior to being sent to production for design. In the last four Ohio projects, no utility line cuts occurred. Curtice Malone of ODOT (personal communication, March 2000) stated that SUE is utilized to prevent damage to utilities particularly when they lack confidence in the locations provided by the affected utility. Most of the projects in **Texas** were not yet in the construction phase when the FHWA report was completed. Seven of the 27 Texas projects are under or have completed construction, and none have reported, as per TXDOT and SUE providers, a line cut as of March 2000.

Table 1. *Utility Line Cut Accidents and Delays on North Carolina SUE Projects*

No.	*Location/ Contact*	*Comments from Contacts on Accidents and Delays*
1	NC 24 Greg Stevens	Not yet under construction, but SUE has located all potential locations of field utility conflicts and resolved them.
2	Hickory Robert Wilcox	SUE Identified potential conflicts, but there were no delays, since SUE allowed the conflicts to be resolved in the field.
3	NC 168 Ron Wilkins	No delays or accidents due to utility conflicts were encountered on the project. SUE allowed 4500' of 8" water line to stay in place.
4	Forsyth Co. R Worthington	No delays due to utility conflicts that he is aware of. SUE allowed NCDOT to modify the bridge structure design to miss a waterline.
5	High Pt Bridge Doug Kimes	No delays or accidents due to utility conflicts. Good cooperation with utilities on a double shift project.
6	I-85 Guess Rd Murray Howell	No utility conflicts or delays were encountered on this project. SUE allowed critical utility locations for design and scheduling.
7	I-95 @ Halifax Dave Boyd	Project had no accidents, delays, or utility conflicts. SUE allowed bridge design to avoid buried utilities without relocation.
8	I-40 Rest Cntr. W. K. Braswell	No delays or accidents due to utility conflicts. SUE located existing crossing of I-40, saving new boring under I-40.
9	Raleigh OLCA Tom Cooney	Utility conflicts were found not to be extensive. No delay-causing utility conflicts were found on the project.
10	Raleigh OLCB Wiley Jones	No accidents or delays due to utility conflicts or cuts. SUE allowed phone cable to be relocated, avoiding a certain line cut.
11	Bethel Bypass Corey Bousquet	SUE Identified all conflicts. No delays or accidents due to utility conflicts or cuts were encountered on the project.
12	Capital Blvd., Ron Hancock	SUE was used to avoid unnecessary relocation of 5,000' of 16" waterline. A few minor field conflicts reported, none caused delay
13	Fuquay-Varina B. Harrington	SUE allowed utility relocations in less ROW width. The result: no utility conflicts were encountered during construction.
14	US 64, Hndr'sn Ron Wilkins	SUE allowed 350 of 16" water main to stay. SUE allowed excavation to be completed without utility conflicts and damages.
15	US 70, Smtt'vle Mike McKeel	SUE found conflicts that were routinely resolved by project redesign. No delays due to utility conflicts or cuts encountered.
16	NC 105, widen Frank Gioscio	No significant delays or cuts of utilities occurred on the project. Two minor conflicts were encountered, but no delays incurred, while contactor worked elsewhere
17	U-2538, Doug Kimes	SUE resolved conflicts with the gas line, which was relocated at several locations with no delays. However, a gas line was cut by contractor's personnel.
18	Capital Bl. US1 Ron Hancock	SUE was used to determine that sewer and water lines were not in conflict and did not have to be relocated.
19	Duraleigh Road Ron Hancock	SUE saved utility line relocations. No utility conflicts were encountered in the field. SUE reduced project line cut accidents.
20	Monroe Rd SR 1009 J Cravens	SUE found numerous field conflicts, which were resolved without accidents. No cuts or delays resulted from utility conflicts.

No.	*Location/ Contact*	*Comments from Contacts on Accidents and Delays*
21	US 17, Onslow Co. Ro Wilkins	SUE saved the relocation of 10,000 feet of water line.

Benefits of SUE according to FHWA

Paul Scott of the FHWA was the Contracting Officer's Technical Representative on the FHWA Report. Paul Scott reported that to his knowledge, there have been no underground utility line cuts on construction projects where SUE was used during the design stage. The only exceptions have been in several cases where SUE information was not made available to utilities; and when the utility responded to a one-call notification and marked the utility incorrectly just prior to excavation. The greatest benefit of SUE is that it enables designers to design around underground utilities, thus avoiding costly relocations and the need to excavate near utilities. Where highway/ utility conflicts are unavoidable, the use of SUE enables designers to precisely locate underground utilities and produce an accurate design. This greatly reduces the possibility of an accident (Paul Scott, personal communication, March 2000).

Savings due to Accident Reduction

In the FHWA report, accident reduction in 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 2. 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 2, the amount of the general liability premium is based on the need to pay all accident claims.

Table 2. *Savings Due to Accident Reduction*

ITEM	**OHIO**	**TEXAS**
I. GENERAL LIABILITY SAVINGS General liability manual rating calculations for Ohio and Texas were made as follows:		
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 Another possible savings included in the FHWA report was the reduction in a contractor's Experience Modification Rating (EMR) which results in lower Worker's Compensation (WC) payments. The FHWA report concluded that the EMR could be reduced by 0.05 over time with SUE for both Ohio and Texas		
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

ASCE UTILITY STANDARD ON SUE

A new American Society of Civil Engineers (ASCE) Standard entitled Collection and Depiction of Existing Subsurface Utility Data is in the final balloting stages after being developed as a consensus standard by the ASCE Codes and Standards Activity Committee (CSAC). The purpose of the ASCE Standard is to provide a procedure to classify subsurface utility data for use in the design and construction industries. The ASCE Standard includes the definitions of utility-information quality levels that allow design engineers to prepare specifications and plans with confidence that the utilities shown are to some standard.

The ASCE Standard specifies the duties and tasks that the engineer, designer, and project owner should accomplish to obtain and provide subsurface utility data. The purpose of the Standard is to clearly define quality-level attributes and the allocations of risk. This Standard will benefit the design professional, the project owner, and the contractor on projects involving excavation activities. The Standard provides guidelines and describes the attributes for depicting subsurface utility information. The format for providing SUE data and information to the designer is demonstrated by specific examples that have been effective on past projects. Examples of mapping deliverables complete with legends, abbreviations, and notes are given in the Standard. An important section of the standard describes how SUE is queued into the design process. Aspects of SUE begin in the early project development phase, continue through the design process, and also are used as a damage prevention mechanism during construction. Finally, the Standard provides a discussion and explanation of the relative costs/benefits ratio of quality levels with cost savings and the costs of obtaining quality level information. (Lew, Lew, Harter, 2000)

OTHER DAMAGE PREVENTION STUDIES

Common Ground Study and NTSB Safety Study

The Common Ground study of one-call systems and damage prevention best practices was completed in August 1999. The study was sponsored by the United States Department of Transportation, and the Office of Pipeline Safety. The purpose of the study was to identify and validate existing best practices performed in connection with preventing damage to underground facilities. The study stated that damages to underground facilities are usually preventable and most frequently occur due to a breakdown in the damage prevention process. A major conclusion of the study was that planning and design must be recognized as an integral part of damage prevention. One of the examples of best practices for damage prevention in the design phase of a project was Subsurface Utility Engineering. According to the study, the engineering process of SUE reduces job hazards and costs, and enhances safety by eliminating unexpected facility conflicts, minimizing facility relocations. A similar study by the National Transportation Safety Board (NTSB) determined that excavation construction activities are the largest cause of pipeline accidents. The Safety Board concludes that providing SUE information to planners can reduce conflicts between underground facilities and excavators. (NTSB, 1997)

Alliance for Telecommunications Industry Solutions

The Alliance for Telecommunications Industry Solutions (ATIS) report noted that facility failures continue to be the leading contributor to outages in the Public Switched Network (PSN). Approximately 50 percent of the FCC reportable service outages have been caused by facility outages. Roughly 33 million customers over the past three years, or 30,000 customers per day, have lost access to the PSN for an average of 5 hours. Over 50 percent of the facility outages were categorized as Fiber Cut Dig-Ups caused by excavators. SUE is an example of a current best practice for identifying subsurface facilities prior to construction in the design stage. (ATIS, 1996)

Federal Aviation Administration Final Report

The Federal Aviation Administration (FAA) *Final Report: Cable Cuts: Causes, Impacts, and Preventive Measures* chronicled reports and events which are a serious cause of aviation safety concern: two are cable-cuts to telecommunications and to electrical power systems. The study found a broad range of causes for cable cuts; but by far the most commonplace cause was construction excavation activities. (FAA, 1993) The report concluded that engineering and construction procedures and technologies could be employed to minimize the possibility of cable cuts. Subsurface utility engineering was included as a primary method to locate cables in the project design phase.

RESULTS AND CONCLUSION

The application of SUE in the design phase of a project provides safeguards to assist in the safe construction of a project. Employing SUE in the project planning cycle from the start of project planning is the recommendation and conclusion of all of the major studies examined in the paper, and from the surveyed state DOT officials. SUE can be used to offer a utility company aid in the marking and locating of underground utility lines in the field during their one-call responses during construction. SUE can be used to find and locate underground lines that are not typically marked, and safely deal with them. Unknown or abandoned utility lines, for example, are now mapped, where in the past, they might have been considered underground clutter or were ignored by utility owners that were only responsible for protecting their active facilities.

Additional information and the character or condition of underground utility lines can be found with SUE. For example, the number of utility lines in one common trench is routinely indicated as part of the SUE deliverables. In the case of five lines in a trench, a contractor who is not using SUE would only find one line (as marked on the ground during construction), and would assume it is the only line on the project. The contractor would then destroy the four other lines. SUE allows more information to be in the contractor’s hands for safety and risk management. When utility exposure is required, the typical practice is via safe SUE means, usually with air-vacuum methods. SUE then provides an above-ground marker for every test hole. SUE shows where underground utilities are located, their condition, material, and other observable and measurable attributes.

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