Guidelines for considering construction safety requirements in the design process

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Abstract

Considering a process view of design, this paper presents guidelines for integrating safety into that process in the construction industry. Two major sources of evidence were used for developing the guidelines: (a) interviews with seven designers from the construction industry; (b) an empirical study of the integration of safety into design in an industrial building project. It is proposed that design for construction safety (DFCS) is organized as a multi-stage managerial process, starting with a preparatory stage involving decision-making on the major standards to be adopted during that process (e.g. stakeholders and their responsibilities). Then, the proposition is made that, during all stages of design (e.g. conceptual design, executive design), the safety integration into that process follows the stages of the risk management cycle: identification, assessment, response and monitoring. The risk management tasks should be supported both by existing databases of practical suggestions to integrate safety in the design and by a set of DFCS principles. In this respect, based on the above-mentioned sources of evidence, this study has proposed ten DFCS principles.

Keywords: safety; design; risk management.

1. Introduction

Both in construction and other industries, the consideration of safety requirements since the early design stages has been widely recognized as a beneficial approach for safety management, since it is an effective way of either reducing or eliminating hazards at their sources. Moreover, once hazards are anticipated at the very early project stages, there will be more time available to plan safe construction methods. Regardless of this, negligence of safety issues during design has been pointed out as a major category of accidents root causes in construction sites (Gambatese et al., 2007; Behm, 2005; Churcher and Starr, 1997). For instance, based on the review of 224 fatalities in the USA, Behm (2005) concluded that in 42% of the cases poor design was a major contributing factor for the accidents. Churcher and Starr (1997) analyzed a large number of fatalities from 1986 to 1989 in the UK and concluded that 36% of the cases were strongly linked to design failures.

The demand for considering safety requirements into design seems to be stronger in the European Union countries that have adopted the European Directive 92/57/CEE (Temporary and Mobile Construction Sites). This Directive makes it mandatory that designers carry out formal safety risk analysis. According to Lakka and Sauni (1999), the European regulations have changed the focus of accident liability towards those responsible for safety planning, including designers and owners. During both design and construction stages, Directive 92/57 requires a health and safety coordinator (a person or a company) assigned by the owner. In Finland and France, owners have often designated the architect as the coordinator during the design phase (Lakka and Sauni, 1999). According to Gambatese et al. (2007) architects are more likely to have a positive impact on construction safety compared to electrical, mechanical and civil engineers.
Legal pressures have also contributed to make safety an integral part of design in the USA, even though in that country there is no equivalent to the European Directive. In the USA, Prugh (1996) has reported the increasing incidence of litigations against designers, mostly architects, due to their negligence in considering safety requirements during the design process. According to Hecker et al. (2006), even though design for construction safety remains in its early stages in the USA, there are several signs that the situation is starting to change. Those authors presented a set of academic and government led initiatives that have been undertaken in the US to disseminate the design for construction safety concept.

However, a number of barriers for integrating safety into design have been pointed out by Hecker et al. (2006), Mackenzie et al. (2000) and Hinze and Gambatese (1996), such as: (a) in the USA, there are liability fears on the part of architects and engineers for becoming involved in construction site safety; (b) design for safety reviews may increase professional fees; (c) tight project schedules established by owners may discourage a thorough analysis of safety issues in favor of other design requirements; (d) the lack of information and high uncertainty, noticeably in early design stages; (e) the limited education architects and engineering designers receive on construction safety; (f) limited availability of safety-in-design tools, guidelines and procedures; (g) limited pre-construction collaboration between the designer and constructor due to the traditional contracting structure of the construction industry; (h) the narrow specialization of construction and design professionals, which may make it difficult their involvement in safety management.

Regardless of those drawbacks, several studies have proposed practical safety measures to be adopted in design (Hislop, 1999; Hinze and Gambatese, 1996; MacCollum, 1995; Fundação Européia..., 1989). In the UK, the Health and Safety Executive has developed web resources that provide a number of case studies and practical suggestions aimed at supporting designers’ compliance with the Construction Design and Management Regulations, which are based on the European Directive (Safety in Design, 2007; Design Best Practices, 2007). Construction and maintenance workers could also benefit from a set of safety solutions in design proposed by Sinnott (1985) for the safety of end users.

However, the practical use of the solutions proposed by those studies is not always straightforward. Some of the design suggestions are specific for certain climate conditions (e.g. when designing ramps, take into account sun orientation in order to minimize snow accumulation), while others are vague or out of the scope of product design (e.g. schedules should minimize the use of overtime). Moreover, their underlying principles are often unclear, since these have not been systematically analyzed in previous studies. Of course, those principles could be fairly easy deduced from the myriad of design suggestions existing in the literature. The lack of such principles might also explain why there are not yet tools to assess the extent to which designs comply with the design for safety concept.

Moreover, there is also room for investigating design solutions that could be applied by the designers of construction equipment and materials, such as cranes, hammers, drywalls, masonry, formwork and utilities. In fact, this means that the design for
construction safety concept should ultimately involve the whole supply chain. Some design solutions related to the design of equipment and material (e.g. redesign masonry blocks with hand holds and design bent handle hammer) were compiled by Schneider and Susi (1996), even though those authors recognize that the solutions should be evaluated as to their efficacy.

While some research topics have been fairly well explored, such as the proposition of practical safety measures to be adopted in design and reports on the implementation of the European Directive 92/57, other dimensions of this subject have not been sufficiently investigated, such as the integration of safety into design from a process perspective. In fact, if design is considered as a process composed by an agreed set of procedures, it is necessary to establish how safety should be positioned within such a broad framework (e.g. in what design stages should safety issues be introduced? What stakeholders should perform a role to integrate safety into design? How safety could be integrated into existing design models and tools?). An exception detected in the literature review is the guidance developed in the UK by the Construction Industry Research and Information Association (CIRIA), aimed at supporting designers to comply with regulations. It takes a broader perspective of the design process and it shows designers how particular hazards that have been raised during the early stages of the design process can be tracked through project files and all decisions recorded (Churcher and Starr, 1997).

In this context, this article has the objective of proposing guidelines for integrating safety into design from a process perspective in the construction industry. It is based on two major sources of evidence: (a) interviews with seven designers from the Brazilian construction industry and; (b) an empirical study of safety integration into design in an industrial building project in Brazil.

2. Research method

In addition to the literature review, this study involved four other stages in order to develop guidelines for integrating safety into design:

a) interviews with designers from the construction industry: seven semi-structured interviews were carried out with designers in order to obtain their perceptions on the integration of safety into design. While four designers were structural engineers (interviewees A, B, C and D), the remaining three were architects (E, F and G). They all had at least 15 years of experience and the majority worked for private clients (85.7%), mostly from other industries (71.4%), such as manufacturing and petrochemical. The reports were grouped into five topics: main assessment criteria adopted by clients; strengths and weaknesses of the design processes in which the designers have been involved; previous experiences in considering safety into design; opinion on the hypothetical introduction, in Brazil, of a regulation that makes it mandatory that designers take safety into account into design and; barriers to integrate safety into design.
b) development of a check-list of safety measures to be integrated into design: a check-list containing a number of suggestions of safety measures was developed to be used in the design process. The main sources of information used to develop such checklist were the interviews mentioned in the previous item and the studies of Hinze and Gambatese (1997) and Sinnott (1985).

c) empirical study: this study was conducted in the enlargement of an industrial building of a plastic manufacturer. The duration of the project was six months, including the time necessary to finish the architectural design and the development of structural and building services design. The construction company that was in charge of this project was a medium-sized firm, which typically carries out industrial, commercial and hospital projects. Such company has its safety management system fairly well integrated to the production planning and control system. It usually works for private clients that have strict safety requirements. This study adopted an action research strategy, since both researchers and the construction company staff worked in close collaboration to effectively integrate safety requirements into design.

d) proposal of guidelines for integration: the guidelines were developed based on both the literature review and the data collected in all of the previous stages of the research method.

3. Results

3.1 Interviews with designers from the construction industry

Cost and time are the main assessment criteria adopted by the clients of the interviewed designers – each obtained 38.5% of the total of criteria mentioned. It is worth noting that cost and time, as reported by the interviewed designers, are related both to the cost and time necessary to develop the design (i.e. drawings and specifications) and to the cost and time expected in the construction stage, which to a great extent are a result of design decisions. The reported criteria are not necessarily in conflict with safety. For instance, the criteria mentioned by designers A (flexibility for future building enlargements) and B (effective matching solutions among construction subsystems, such as walls and utilities) tend to have a positive impact on constructability and, as a result, on safety. All designers reported that they informally take into account constructability requirements.

The designers also reported some of the characteristics of the design processes in which they have been involved. Four out of the seven designers (51.7%) complained that clash detection meetings were very time-consuming and that their active participation occurred during little time. Nevertheless, designer G reported that clash detection meetings with representatives of all design disciplines were a major opportunity to learn about the project.

Designer A emphasized the importance of involving the owner as early as possible into the design process. This involvement tends to be critical for safety, since the owner will
be the ultimate decision-maker that will either approve or not design changes that have an impact on safety issues. Designers C and D reported they had a design practice that indirectly supported hazard identification: the use of checklists during early design stages to identify features of the structural design, such as the type of brick and the type of water reservoir. None of the designers reported that they developed production-oriented designs that specified sequencing and construction methods, which is negative from a safety perspective.

Only designer C (pre-cast concrete structures) reported that he voluntarily took into account safety of construction workers in his designs. This attitude is probably due to the fact that that designer has been working for fifteen years nearly on a full-time basis to the company that manufactures and installs the pre-cast concrete structures. Therefore, differently from the other designers that were interviewed, designer C works in close collaboration with the contractor and so he will be directly affected by design decisions that neglect safety and constructability. However, designer C emphasized that his focus is on safety during the manufacturing and assemblage of structures by the pre-cast concrete manufacturer personnel. Little or no attention is given both to maintenance and to the impact of the assemblage of pre-cast structures on safety of other construction crews. In fact, when firms bring the design and construction functions and personnel into the same entity, they improve the opportunity for integrating safety, usually a constructor concern, into design (Hecker et al., 2006).

The designers also emphasized that safety requirements to be integrated into design should be primarily pointed out by the owner and the contractor, especially the latter, since from a legal perspective it is the main accountable party concerning safety during the construction stage. Nevertheless, designers perceive that owners and contractors are rarely concerned with safety into design, so there is inertia from all involved parties.

By contrast, three out of the seven designers reported that, even though their clients are not concerned with construction safety, they are usually concerned with safety of end users of the buildings. For example, one of the designers reported that some of his clients demanded the development of formal fire risk assessments during electrical designs for industrial buildings. For those three designers, it could be easier to consider safety requirements of temporary users, since similar risk assessment techniques might be adopted both for end and temporary users.

Even though all designers have been able to mention at least one construction or maintenance safety hazard derived from their design solutions, none of them formally communicates hazards to contractors and owners. The reports also pointed out several barriers for considering safety into design: (a) the lack of feedback about poor constructability and safety hazards during construction and maintenance that were a result of poor design decisions; (b) the insufficient knowledge of designers on safety issues; (c) the lowest price criteria adopted by government agencies to select contractors; (d) the budgets that ignore the costs involved in building maintenance; (e) the designers and owners resistance to accept their share of responsibility for construction safety; (f) the lack of full implementation of the Brazilian Code of Consumers Rights, since there is usually no legal penalties for those designers that created latent conditions that favored
accidents during maintenance; (g) the perception that constructability can only be achieved through expensive technological solutions; (h) the lack of proper identification of both temporary and end users requirements since early design stages, which provokes a lot of rework either or not the issues are related to safety. Barriers (b) and (e) are equivalent to barriers found in the USA and EU reported by Hecker et al. (2006), Mackenzie et al. (2000) and Hinze and Gambatese (1996).

All designers also considered that the introduction of mandatory requirements to integrate safety into design would be an important step to move the industry towards a better safety performance. Moreover, they perceived that developing designs that can be safely built should be considered a matter of professional ethics. However, they pointed out two potential barriers for introducing this new requirement in Brazilian regulations: (a) the lack of enforcement by government agencies, which is a frequent problem for many other regulations in Brazil; (b) the perception that most owners would not be willing to pay higher professional fees for this new task. According to the designers, those problems tend to be more serious in the residential building construction industry, since in this sub-sector the predatory competition among designers is more frequent and the profit margins are lower.

3.2 Analysis of suggestions for integrating safety measures into design

It was developed a checklist with 49 suggestions for integrating safety into design. The share of suggestions assigned to each design discipline was as follows: architecture (45.8%); structure (33.3%); utilities (20.8%). In order to clarify the nature of the proposed suggestions, they were analyzed from two perspectives: the hazards they were supposed to tackle and their underlying design principles.

Considering that 53 hazards were associated with the 49 proposed suggestions, the analysis pointed out that 45.3% were hazards of falls from different levels, 11.3% were primarily production hazards (i.e. there could be re-work or unnecessary tasks could be created if the suggestion was not followed), 9.4% involved hazards of being struck against, 7.6% were hazards of falls at the same level, 7.6% involved awkward postures or overexertion, 5.7% involved structure collapses or cave-ins, and 13.1% involved other hazards, such as electrical shocks, fire, cuts and run over.

Moreover, the analysis pointed out that the 49 suggestions adopted the 10 design for construction safety principles that are presented below (of course, this implies that each principle was underlying more than one suggestion):

(a) design to make it easier the installation of safeguards for construction and maintenance – e.g. design holes in columns to pass lifelines and guardrails. This principle was used in 26.1% of the total of suggestions;
(b) design to avoid interferences both among different building elements and among specific building elements and temporary/pre-existing site facilities (23.9%) – e.g. avoid designing stairways opposite to glass doors and/or glass windows;
(c) design accesses for carrying out maintenance tasks (15.2%) – e.g. incorporate ladders in the final structure to allow access to roofs;
(d) design building elements that can perform the role of safeguards, making them unnecessary (8,7%) – e.g. design parapets at least 1,20 m height, which is the guardrails height required by regulations;
(e) anticipate accidental loads during the construction stage (6,5%) - e.g. Brazilian regulations require the installation of platforms all around the building to gather residuals of construction materials during the execution of the external envelope;
(f) improve hazards visibility (6,5%) – e.g. specify colors of formwork panels that contrast with ironwork;
(g) design to prevent work at height, specifying tasks that can be done at ground level (4,4%) – e.g. design concrete and steel structures that can be pre-assembled at ground level;
(h) design to make it easier respond to emergencies (4,4%) – e.g. place mechanical, hydraulic and electrical switches in visible and readily accessible areas;
(i) do not design parts with sharp edges and that tangle (2,2%) – e.g. design rounded edges of guardrails rather than sharp edges;
(j) design to incorporate temporary facilities into the final structure (2,2%) – e.g. place crane foundations where they do not need to be demolished. This suggestion aims at preventing unnecessary workers´ exposition to the hazards involved in the demolition of the crane foundations.

3.3 Empirical study

Approach adopted for integrating safety into design

Due to time pressure, the construction stage started without completion of all designs. Therefore, demands for both developing new designs and modifying existing designs were frequent during the construction stage. While the owner assigned the architect as both its representative in the design process and the coordinator of that process, the contractor assigned a member of top management and a production engineer as its representatives during the design meetings. On a weekly basis, during two months, there were meetings to match the different design disciplines at the contractor´ headquarters. In addition to the owner´ and contractor´ representatives, those meetings also had the attendance of other designers whose disciplines were related to the subject of the meeting.

One of the authors attended just two of those meetings, since they were usually too time-consuming and the discussion of a myriad of design requirements made it difficult to introduce the discussion of safety issues. However, the attendance of those meetings helped the researchers to improve their understanding on the scope and details of the project. Overall, four major steps were carried out in order to integrate safety into design: (a) to analyze both architecture and pre-cast concrete structure designs from a safety perspective, since those were the only disciplines that had existing conceptual designs when the study began; (b) to develop a list of potential safety requirements to be taken into account by designers, with the support of the checklist of safety suggestions that had been previously developed; (c) to discuss that list with the designers both on an individual basis and during the weekly clash detection meeting; (d) to assess the extent to which the requirements were actually taken into account during the construction stage,
based both on an interview with the production manager and on visits to the construction site. While stage (c) was undertaken by the contractor’s representatives in the design process, the remaining tasks were carried by a member of the research team.

Results of the integration

Table 1 shows how safety requirements were documented in the empirical study. It is worth noting that although just the architecture and pre-cast concrete structure designs were analyzed, it was possible to identify safety requirements related to other design disciplines that were in early development stages, such as steel framing and roofing.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Justification</th>
<th>Design discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Anchorage points at the beams of the steel frame that supports the roof</td>
<td>Attach lifelines for both body harnesses and tower scaffolds, making it safer both construction and maintenance</td>
<td>Steel frame</td>
</tr>
<tr>
<td>2. Anchorage points at the external face of columns</td>
<td>Attach lifelines for both body harnesses and tower scaffolds, making it safer both construction and maintenance</td>
<td>Precast</td>
</tr>
<tr>
<td>3. Protect steel sharp edges of the precast columns</td>
<td>Avoid being struck by or struck against those steel sharp edges</td>
<td>Precast</td>
</tr>
<tr>
<td>4. Ladders to access the roof from outside of the building</td>
<td>Safe access to the roof both for construction and maintenance workers</td>
<td>Architecture</td>
</tr>
<tr>
<td>5. Lifelines on the roof</td>
<td>Safety during roofing and roof maintenance</td>
<td>Roofing</td>
</tr>
<tr>
<td>6. Development of a mechanism to change lamps in high ceiling areas</td>
<td>Safety during changes of lamps in high ceiling areas</td>
<td>Electricity and architecture</td>
</tr>
</tbody>
</table>

Table 1. Safety requirements detected in the empirical study

Requirement 1 (anchorage points for both body harnesses and tower scaffolds at the steel beams that would support the roof) was eventually considered unnecessary. This was due to the fact that the contractor that was responsible for designing, manufacturing and installing the steel framework, proposed that lifelines were directly anchored at the trusses, which are illustrated in Figure 1. This contractor also presented a standard plan it used as a basis to assemble the steel frame – of course, this plan was adapted to this specific construction site. Requirement 2 (anchorage points for both body harnesses and tower scaffolds at the precast concrete columns, which were 12 m length pieces that had several iron sharp edges throughout it) was easily implemented, since the manufacturer usually installs some anchors to make it easier the transportation of the precast pieces. It was also made the decision to make holes in the columns in order to pass lifelines, at the heights of 3,0 m, 6,0 m and 9,0 m.
Requirement 3 (cover iron sharp edges along the pre-cast columns) was also implemented. Due to the contractor request, all edges were bent before being delivered in the construction site. Requirements 4 and 5 (ladder to access the roof and lifelines over the roof, respectively) were implemented, in spite of some delay to determine the exact position of the ladder. Requirement 6 (mechanism to change lamps at high ceiling areas) was not implemented, since it was not found a more effective solution than the one currently adopted by the owner. In the existing building, the owner crews change lamps with the support of forklifts and cranes. Long life light bulbs could have been specified in order to reduce frequency of maintenance (Design Best Practice, 2007).

4. Guidelines for integrating safety into design

This study proposes to organize DFCS as a multi-stage managerial process. It should start with a preparatory stage involving decision-making on the major standards to be adopted during that process, such as: (a) who will be the stakeholders and what will be their responsibilities; (b) what will be the adopted risk management techniques; (c) what will be the level of detail of the safety plans; (d) what sources of information will be required to carry out the risk management tasks (e.g. blueprints, accident statistics, etc.); (e) what will be the metrics to assess the effectiveness of the DFCS effort. Although the data collected in this study are not sufficient for proposing detailed guidelines on each of these issues, some guidelines might be proposed concerning the responsibilities for analyzing each design from a safety perspective.

Of course, this responsibility should be ideally attributed to designers, since more than any other stakeholder they have control on the creative process, maturity level of design solutions and the pace of the design. In particular, it is critical that the architect take the initiative to integrate safety into design, since its discipline has usually the strongest interfaces with all remaining disciplines. Moreover, the architecture design usually includes specifications on materials and construction methods for several building elements that often do not have specific designs, such as masonry and floors.
The little safety knowledge of most designers may be minimized if they carried out risk assessments with the support of production managers and safety specialists. While the production manager might provide essential information on construction methods and their associated hazards, safety personnel will provide specialized advice to designers. Gambatese et al. (2007) suggest that the design for construction safety intervention requires a team-oriented approach relying on collaboration of the designer, owner, constructor, and other project parties for it to be meaningful. In fact, since the design team should have a realistic mental model of temporary users’ behavior, it would be desirable if lower hierarchical levels could be involved, such as foremen and front-line supervisors. Since this teamwork will imply additional costs, the contracts between owners and designers should explicitly include the necessity of considering safety requirements and their related professional fees.

The existence of a design coordinator might also support the introduction of safety requirements into the design process. This coordinator could be in charge of both monitoring the designs compliance with safety requirements identified during the design process and sharing safety information with all designers. For instance, as soon as a risk analysis of the architectural conceptual design is available, it should be shared with all designers, pointing out the potential impacts of that analysis on every design discipline. The coordinator also might facilitate the matches among design disciplines due to safety requirements. For instance, the development of means to safely change lamps in high ceiling areas might have an impact on both the architecture and electrical / lighting designs, which in turn will require that they are compatible.

Since the major standards of the DFCS process are defined in the preparatory stage, the proposition is made that, during all stages of design (e.g. conceptual design, executive design), the practical safety integration into that process follows the stages of the risk management cycle (Baker et al., 1999): identification, assessment, response and monitoring. Although the four stages of the risk management cycle should take place during each major stage of design, it is likely that after the conceptual design, only revisions will be necessary. It is worth noting that a revision of the risk management cycle will also be useful after developing the as built design, mostly to check hazards related to maintenance.

In the design language, hazard identification is equivalent to capturing client requirements, which in this case are construction and maintenance workers. However, the characteristics of the workforce should not be taken for granted by adopting stereotypes of construction workers. In fact, designers should have a realistic image of the temporary users, both from a physical and cognitive perspective (Hollnagel and Woods, 2005). For instance, there are reports that in some European countries the demographics of construction workforce has changed drastically due to the increasing amount of migrant workers who do not have a command in English (Bust et al., 2007). High rates of illiteracy and a substantial amount of more than forty-years old workers is also a well-known characteristic of the construction workforce in Brazil. While it is a neglected issue in literature, construction workforce is also formed by a substantial amount of impaired and disabled people, whose physical and cognitive skills are compromised to some extent. According to Newton and Ormerod (2005), while contractors are unlikely to recruit
disabled people, they are more likely to continue to employ people once they become disabled, but there is very little monitoring of this process by contractors. Further studies are necessary to investigate the implications of such workforce characteristics on product and process design.

A set of well-known techniques might support hazard identification, such as failure mode and effects analysis, meetings involving designers and production personnel, check-lists of hazards and their respective design suggestions, constructability reviews, 3D or 4D simulations of construction and, prototypes of some building elements. Those techniques are also likely to support the assessment and response risk management stages.

Risk assessment is the second stage of the risk management cycle. It includes the understanding of the nature of all hazards previously identified, setting up the basis for calculating a risk index (severity versus probability) associated with each design discipline. However, a thorough understanding of all hazards tends to be very difficult during early design stages, since there is usually a substantial uncertainty concerning the construction methods. This uncertainty has also an impact on the calculation of the risk indexes, which might support the prioritization of construction stages in terms of safety management efforts. Therefore, calculated risk indexes should be revised on a regular basis (e.g. by the end of every design stage) in order to take into account varying levels of uncertainty during the design process.

Risk response is the third stage of the risk management cycle, involving the definition of measures to control the hazards that were previously identified and assessed. According to Baker et al. (1999) there are four typical responses to hazards: elimination, reduction, transfer and retention. The first two types of responses might be developed based on both DFCS principles and existing databases of practical suggestions of safety measures to be adopted in design. Moreover, designers should look for opportunities for devising fail-safe barriers, which is an approach consistent with the dynamics of construction sites and with the previously mentioned fact that the construction workforce is increasingly diverse. A fail-safe barrier is one that prevents an accident from taking place and that has a shutdown function (i.e. no degrees of freedom are left). Based on this concept, fail-safe barriers can only be physical or functional barriers. According to Hollnagel (2004) physical barriers block the transportation of mass, energy or information from one place to another (e.g. walls and fences) and functional barriers create one or more pre-conditions that have to be met before an action can be carried out (e.g. by establishing an interlock, either logical or temporal).

It is essential to identify the hazards that were not eliminated during the design and, as a result, will require management efforts during the construction stage. Of course, it is worth emphasizing that design decisions do not necessarily should be modified to eliminate safety hazards. Even hazard retention can be acceptable in the case that an architectonical element adds value to the client, in spite of being difficult to be built. Indeed, this hazard retention only makes sense if it implies that there will be safe and effective construction methods. In other words, there can be sometimes a trade-off between temporary users and end users requirements. It is worth checking whether this trade-off is real, since end users requirements are not often systematically identified and
so there can be a big gap between the designers’ image of end users requirements and their actual needs.

Hazard monitoring is the last stage of the risk management cycle and it takes place during both the design and construction stages. During all design stages, hazard monitoring should involve tracking of hazard identification, assessment and response. Concerning the construction stage, monitoring should ensure that the safety measures specified in design are implemented. The resulting feedback will be useful for developing safer designs in the future.

It is also proposed that the risk management related tasks (e.g. identifying hazards and devising preventive measures) should not be primarily undertaken during clash detection meetings. This proposition is due to the fact that those meetings might be too long, involving too many people and dealing with a myriad of design requirements. Decision-making on safety issues is likely to be realized as less urgent than other decisions that are essential to allow the beginning of construction. Of course, clash detection meetings might perform an essential role both as a source of information for undertaking risk management tasks and as a forum to ideas exchange among the stakeholders.

5. Conclusions

Based on interviews with seven designers from the construction industry and an empirical study, this paper proposed guidelines for integrating safety into design. It is proposed that the design for construction safety (DFCS) process starts with a preparatory stage involving decision-making on the major standards to be adopted during that process (e.g. stakeholders and their responsibilities).

Based on the preparatory stage, the four steps of the risk management cycle (hazard identification, assessment, response and monitoring) should take place during every major design stage (e.g. concept, outline, scheme, detail). The tasks of the risk management cycle might be carried out based on both well-known risk management tools and databases of design suggestions available in literature. Moreover, risk management might be supported by ten DFCS principles that were compiled for supporting the empirical study.

This research has pointed out opportunities for further studies in this area, such as: (a) the improvement and testing of the proposed guidelines – in fact, these guidelines could be a basis for developing a well structured DFCS method; (b) the development of other guidelines and methods for integrating safety into design; (c) to extend and validate the set of DFCS principles proposed in this study; (d) develop methods to assess the extent to which a design is safe. These studies should consider the existing models of the design process in the construction industry, so the integration could be based on theoretically agreed perspectives on design (e.g. what is design, what is its scope, what are the major design stages, etc.).

6. References


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