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INTEGRATED SAFETY IN DESIGN

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An on-going research project investigates the inclusion of health and safety considerations in the design phase as a means to achieve a higher level of health and safety in the construction industry. Moreover, the approach is coupled to the overall quality efforts. Two architectural firms and two consulting engineering firms are project participants. The hypothesis is that health and safety problems in execution can be prevented through better planning in the early stages of the construction processes and that accidents are prevented by providing safety. In the first stage of the research project a theoretical framework is developed from a combination of existing literature on health and safety and a mapping of existing practices based on interviews in all four companies. The interviews revealed that the basic knowledge on OHS among architects and engineers is limited. Also currently designers typically consider OHS in execution as a responsibility of the contractors. The output of this stage is a systematic and structured conceptual framework that couples OHS-risks in construction (health, safety and mental health) to the stages in the design and engineering processes. Moreover the framework includes a focus on processual elements, constraints and prevention strategies and also includes a tool to address OHS risks in the design processes. The approach stresses how complying with legislation should only be seen as a minimum condition in design and engineering. Incentives to prioritize OHS in design and the possibility to cultivate OHS under agendas on quality and sustainability are discussed. The second stage of the project test the framework from intervention on up to four construction projects followed by an evaluation of the results and processes.

Keywords: Construction, design and build, health and safety, intervention

INTRODUCTION

Over the last decade the rate of accidents in the Danish construction industry has been almost constant between 24.4 to 30.7 accidents per 1,000 persons employed between 2003 and 2012. In Denmark the rate of accidents in the construction industry was 30.7 accidents per 1,000 persons employed compared to an accident rate of 11.3 in Sweden. Different methods of registration are possible explanations to some of the difference but the numbers are alarming. To formulate an agenda with occupational health and safety as an integral part of the construction projects overall social sustainability approach can be an instrumental way to promote the well-being of employees in the highly profiled agenda on sustainability.

The employees being subject to injuries or fatalities in construction are mostly connected to the onsite processes and the execution phases since this is where the

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employees are exposed to the primary occupational hazards. In Denmark historically the primary facilitator of safety work has been the contractors and initiatives to enhance occupational health and safety (OHS) in the construction industry are often directed towards stakeholders in the execution phases. However already in 1991 the EU documented that a third of the occupational accidents in the construction sector are results of errors in the client's and the consultant's detailed design and engineering, and 1/3 are a result of flaws and defects in the contractor's planning (European Foundation for the Improvement of living and Working Conditions, 1991). This formed the foundation for EU regulations that in Denmark, however, were not deployed through legislation until 2008 inter alia to impose a statutory health and safety coordinator in the design work. Also a number of scholars emphasize how design forms the basis for safety (Smallwood, 1996; Behm, 2005; Toole et al, 2006; Gambatese et al, 2008; Larsen and Whyte, 2013). Moreover, often the OHS focus in design and engineering is often on OHS in operations in the finished building whereas the wellbeing of the construction workers in execution is only being slightly considered.

An on-going research project develops and tests a framework to strengthen the inclusion of health and safety considerations in the design phase in construction as a means to achieve a higher level of health and safety in execution. The aim of this research project has been to establish a structured framework to integrate OHS in design and engineering of construction projects. The hypothesis is that health and safety problems in execution can be prevented through efforts in design and engineering in the early stages of the construction processes. This conference paper presents the overall elements in the first part of the research project which is the development of a theoretical framework from a combination of existing literature on health and safety and a mapping of existing practices based on interviews in four companies. The framework couples OHS-risks in construction (health, safety and mental health) to the stages in the design- and engineering processes. The second part of the project is currently testing the framework from interventions on four construction projects followed by an evaluation of the results and processes.

The central actors that the effort is directed toward are the "designers", which covers architects, constructors, engineers and others who carry out their consulting services in the design phase of a construction project. These actors outline the structures of the construction project both in form of the design for the physical structures but also the organisational and strategic structures, the schedule and so forth. Therefore they actually have the opportunity to design and adapt the projects' fundamental structures to protect the construction workers. Hence, it is a different type of questions that can be "asked to" the project material whereas in the later stages of the construction projects it is either only possible to react to the already given structures or make (often expensive) project changes. If demands for OHS are incorporated in the early project design, it becomes easier to organise the construction site in a safe manner.

The paper opens by presenting the methods adopted to design the framework to integrate OHS in design and engineering of construction projects, followed by a literature section and a section on the initial study of current OHS practices in design and engineering on Danish construction projects. The latter two forms the basis of the design of the framework which is presented in the following section. In the closing section the findings and implications of the approach is discussed and concluded.

METHODS

The research is divided in two coherent stages. The first part of the research project map existing practices and combined with existing literature on occupational health and safety a theoretical framework is developed on how to integrate health and safety considerations in the phases of design and engineering. The methods are primarily qualitative but in the evaluation in the second stage quantitative techniques will also be applied.

The research project uses the work of Jørgensen (2009) as a methodological starting point, which again is based on the lean construction thoughts of Ballard (2000) and Koskela et al. (2002). Jørgensen (2009) developed an initial theoretical framework for integrating OHS considerations in construction design and engineering, which is being further developed in this projects with an expanded understanding of OHS risks and exposures and a more practical take on requirements in the design phases – based on the interviews from stage 1 of the research project.

Empirical setup

Two architectural firms and two consulting engineering firms are project participants. The empirical work in stage 1 included in-depth interviews with 23 architects and engineers conducted at the head offices of the companies. Also thorough discussions were made with a reference group consisting of members from the four companies. The research sought to understand the actual processes of design for safe construction as experienced by the architects and engineers.

These interviews were semi-structured, with an emphasis on facilitating open discussions on the topics. The conversations were steered to make sure that the relevant themes and topics were sufficiently covered.

The second part of the project is ongoing and tests the framework and material through interventions on four to five construction projects followed by an evaluation of the results and processes. This stage is only briefly touched upon in this conference paper. The intervention on the projects consists of workshops, interviews and interactions with participants in design and project planning, mainly architects and engineers. The intervention projects are executed successively through 2014 and the effect of the intervention is evaluated by questionnaires and structured interviews with both architects and consultant engineers but also the contractors are asked to evaluate the project material in relation to OHS; if and how it can be seen to have a higher priority in the projects materials than the usual standard.

SAFETY DESIGN IN CONSTRUCTION

It is widely documented, that the construction industry is risky, both internationally and in Denmark (European Communities, 2004). A number of scholars have determined that safety has root causes in project design. In 1991 a European study found that 60% of accidents could be eliminated or reduced through better design (the European Foundation for the Improvement and Human Rights, 1991). Toole et al., (2006) found that changes in design could reduce 22 % of accidents in construction in the U.S.A. and correspondingly researchers in the UK found that changes in design could reduce 47 % of accidents in construction and that 42% of fatal accidents in construction could be linked to the safety concept for the building design (Gambatese et al, 2008). Behm found that deficiencies in the design process were the main reason for at least 42 of the 230 examined fatalities in 1990-2003 (Behm, 2005). Scholars

have also proved a correlation between project design and accidents in the execution (Gibb et al., 2004; Gambatese et al., 2008).

Ideally the safety of the construction workers in execution should make up an important parameter for designers in the conceptual and preliminary design phases (Szymberski, 1997; Gambatese et al, 2008). The EU directive of 92 (Council Directive 92/57/EEC of 24 June 1992) describes minimum demands for OHS at (temporary) construction locations, and emphasize the role of the building planners (client, architect and consultants) as having the responsible for sketching and outlining a plan for OHS during execution of the construction project. However, in Denmark the directive was not integrated in legislation and deployed until 2008.

Discussions on safety design were pioneered by Perrow (1983) in the production fields and have been a topic since. Ergonomic problems in development of products and processes in the industry has been studied (e.g. Broberg, 2007) as well as activity oriented ergonomic transport (e.g. Lamonde, 1996). Safety design does not simply focus on technical solutions, but also on activities, processes, involvement of users, etc. (Fadier and De la Garza, 2006). Frijters and Swuste (2008) highlights how the knowledge of safety design has not been implemented in the design of most building projects, which is in line with the results of the previously discussed scholars.

The project oriented, dynamic nature of traditional construction can be a barrier to implementing safety but also quality in general into the building process (Loushine et al, 2006; Lingard and Rowlinson, 2005). Also the traditional tendering processes often force a price focus that can compromise or omit a focus on safety (Brooks, 1993). Moreover, traditionally the responsibility to ensure OHS in execution has been that of the contractors (Gambatese and Hinze, 1999; Hinze and Wiegand, 1992) and legislation supports this to some degree. The contractors act as the employers to the construction workers. However, Smallwood (1998) highlights how the client can be the driver to improve the focus and level of OHS (lowering injury rates) on the projects. The client can influence contracts, define the level and focus on OHS and hereby promote OHS considerations to the designers.

A number of scholars describe the amount of influence on safety in the execution phase the designers actually have and how decisions and design in the early phases impact the safety of the construction workers (Hinze and Wiegand, 1992; Gambatese and Hinze, 1999; Thorpe, 2005). Safety design, safety by design or prevention through design in construction is corresponding concepts concerned with how deliberate decisions in the design of the construction project supports safety in execution by removing or reducing OHS risks and exposures to the construction workers' (Behm, 2005; Gambatese and Hinze, 1999; Toole et al, 2006). Safe design can be concentrated purely on technical directions, but often also include a organisational scope e.g. planning methods (Toole et al, 2006; Thorpe, 2005; Frijters and Swuste, 2008). Concrete examples are many, e.g. the Construction Industry Institute (2009) has a catalogue containing over 400 design proposals to design for safety, The Health & Safety Executive's homepage in UK also offers extensive material (HSE, 2009) and in Australia they recommend a special design review form called CHAIR (Workcover, 2001).

THE LEVEL OF OHS IN DESIGN AND ENGINEERING

The study in the first phase of the research project primarily focussed on understanding how OHS is included (or omitted) in traditional design phases in

construction. The primary elements studied was 1) the level of knowledge on OHS among the actors in the design phases 2) the designers view on prioritization, duties and responsibilities in connection to OHS in design and 3) how OHS is integrated in current construction design and engineering processes in general.

The findings reveal that the basic knowledge on OHS among non-OHS-professional architects and engineers is limited. In general the actors have no theoretical approach to OHS. Both architects and engineers "know they have to do something", but they don't know what that "something" is, how to do it and where to look for information in order to remedy this lack of knowledge. Moreover, the companies often do not have a structured, formal approach to deal with OHS concerns. However, OHS is often relevant to the different disciplines in relation to constructability/buildability, but decisions are then based on traditional practical experiences and not on structured OHS knowledge.

In regard to prioritization, duties and responsibilities the study highlights how the designers broadly do not view it as their responsibility to consider the safety of the construction workers. OHS is considered the contractor's responsibility and competence. This correspond a number of scholars (Hinze and Wiegand, 1992; Gambatese et al, 2008; Toole, 2002). If OHS is formally addressed it is often initiated because of the legal duties and requirements or on specific requested from the client. It is to a large degree considered sufficient to comply with legislation and OHS is rarely prioritized further, although legislation should be seen as a minimum. Also the prioritization is affected by the projects' overall framework conditions, organization, characteristics, etc.

OHS-activities are often decoupled from the core activities in design and project planning as a retrospective review of the project in the different design phases rather than an integral part of the design work. The participants' experience, that a strengthened focus on OHS often lead to a better construction process, but only has a small effect on the quality of the product. The study highlights that OHS problems must be addressed very early in the project design; as an explicit part of the formulation of the project goals and values that outlines the priorities in the design processes. The approach must also combine processual elements (a continuous, recurring focus on OHS) and formal gateway reviews/screenings and analysis at the end of every stage in the design process.

The initial study highlights the need to strengthen OHS knowledge and competencies among OHS non-professionals and the demand for a structured and systematic approach to OHS in design and project planning. The investigation further emphasize that to be successful new OHS activities emanating from the research project must be integrated with existing design and engineering practices and parallel to issues such as quality, costs, time, sustainability etc. and not add additional burdens and tasks to the design process.

FRAMEWORK FOR OHS IN DESIGN AND ENGINEERING

The theoretical framework that subsequently was developed couples OHS-risks in construction (safety, health and mental health) to the stages in the design and engineering processes as shown in the figure.

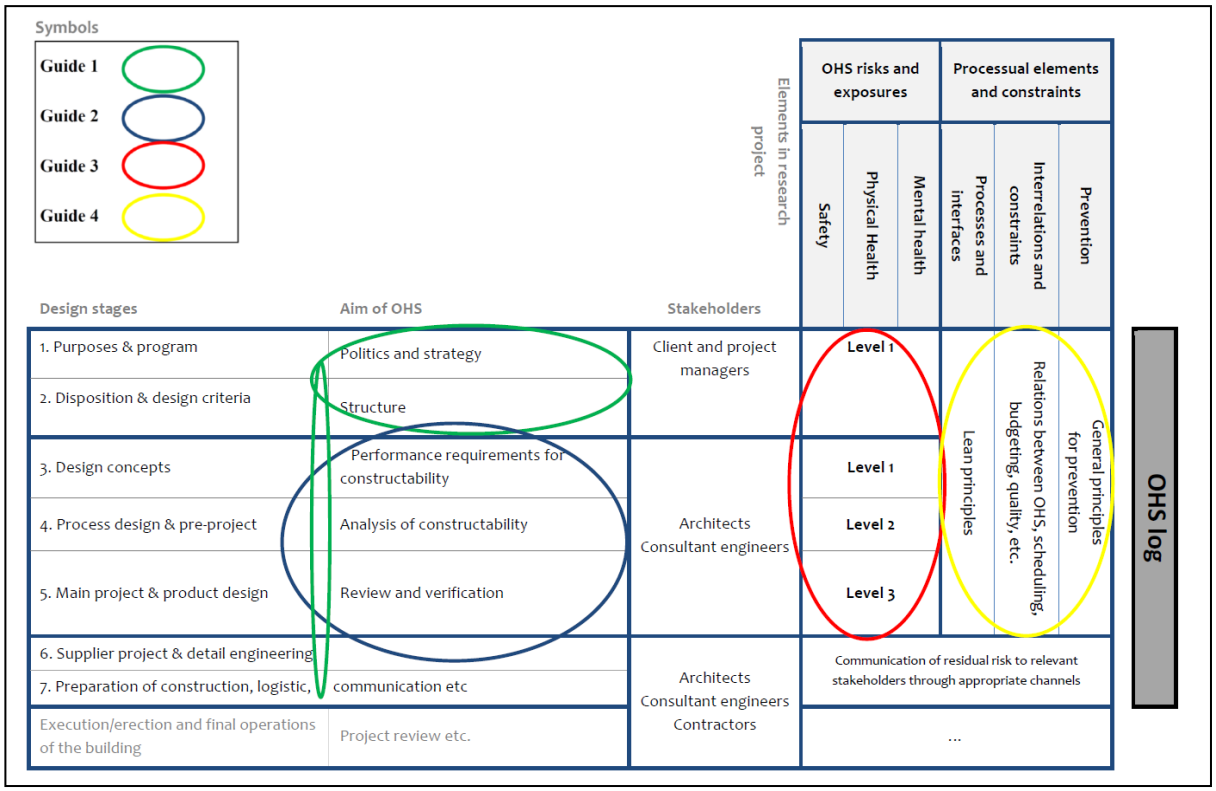

Figure 1: Conceptual framework for integration OHS in design in construction

The vertical axis is divided in seven theoretical design stages derived from Ballard (2000) and Koskela et al. (2002) spanning the timely development of the design of the construction project starting at the initial ideas and ending with the handing over to the contractors. Different contract forms might imply different stage structures.

The aim of the different stages in regards to integrate OHS in design is described in the second column. The third column outlines the normal primary stakeholders/participants of the stages.

An important part of integrating OHS in the design is strengthening the competencies of the participants which are done by presenting the common OHS risks and exposures. The structure on OHS risks is a further development of a structure on common risk to safety in construction (Jørgensen, 2008; 2009; Jørgensen et al., 2010). Based on almost 20.000 hospitalizing working injuries in the Netherlands occupational safety risks has been divided into three levels, which led to four overall groups (level 1), that was divided into 17 subgroups on level 2 and 64 subgroups on level 3 (Jørgensen et al, 2010). This research project has in the same manner divided occupational risks to the physical and mental health into three detail levels from a thorough review of literature, executive orders and regulations from the Danish Working Environment Authority and materials from industry organisation e.g. the Safety Council for the Danish Construction Industry.

To acknowledge that the level of detail in the projects' design is developed through the stages, equivalent the level of detail in the assessment and evaluation of OHS risks and exposures is also developed through the stages. So in the initial stages of the design the OHS risks can be assessed at level 1 (the most general level), in the following stages of design and engineering OHS risks can be assessed at level 2 (adding an extra layer of detail to the assessment) and accordingly in the final stages OHS risk should be assessed at level 3 (the most detailed outline of the risks). An

example at level 1 could be the assessment of the surfaces, where people move or work. This category is subdivided on level 2 into the risk of a) falling from heights and b) falling in the same level. A level 3 assessment in the final stages address the specific work processes, e.g. risks from work on mobile scaffolding.

The last three columns denote that the assessment of the OHS risks must also include the interfaces to adjacent parts of the construction structure but also the interfaces to previous and subsequent actors and processes. Hence, the concept includes a theoretical (and practical) understanding of the processes and interfaces. Moreover OHS is often prioritized and/or balanced with decisions related to the budget, the schedule, quality issues, focus on sustainability and so forth. So the framework describes these interrelations and constraints – but also delivers a number of incentives to prioritize OHS in design. The framework also presents the participants to the general prioritized principles for prevention (Jørgensen, 2013):

1. Evaluate the risks.
2. Preventing the risk at the source.
3. Adjust the work to the workers, especially the design of the workplace, the choice of equipment and the working methods. Avoid monotonous work and work in fixed rhythms.
4. Take the technological development into consideration.
5. Substitute dangerous work, substances and equipment with something less dangerous.
6. Make plans for safety and health as a coherent whole, which include technology, work design, working condition, social relation and risk factors in the working environment
7. Make precautions against collectively prevention instead of individual prevention
8. Be sure that all workers have got a proper instruction of safety in their work

Not all risks can be eliminated in the design stages. The residual risks have to be taken care of, so the framework delivers a plan and a strategy to communicate residual risks to relevant stakeholders through appropriate channels e.g. the plan for safety and health before the construction begins.

Finally a tool has been developed to assess, evaluate and address OHS in construction design - entitled the OHS Log. The OHS Log combines the elements presented above in a dynamic and simple tool that helps the participants to assess the probability and impact of an OHS risk in the design phase and systematically address constraints and options for prevention. The tool can be used continuously in the processes by the designers to pin-point their concerns in regards to OHS in the design processes – based on their (new) knowledge on OHS risks on three levels. But the tool can also be used in formal gateway screenings at the end of each stage of the project. The tool is typically administrated by a senior project manager or a safety coordinator.

The figure also presents how the conceptual framework is presented in four guides to the participants at the projects. These guides are presented at repeated workshops with the design group on each construction project and a project oriented assessment of the OHS risks is carried out at the different stages of the intervention projects. Also the framework is further developed and tested from the intervention projects.

Guide 1 is focussed on the early stages but also the transverse and coordinating considerations in the design stages and hence primarily is aimed at the projects

managers on different levels. Guide 2 is aimed at the designers and consultant engineers and focuses on the corresponding stages in design. These two guides are supplement with further two guides, Guide 3 and 4, that are explanatory manuals; one elaborating specific OHS-risk and another presenting cases of decisions in design and projects planning with either good or bad impact on execution processes.

DISCUSSIONS AND CONCLUSIONS

It is widely recognised in the construction industry and by scholars, that the amount of injuries and fatalities in construction execution is a comprehensive problem and a number of studies highlights how a substantial part of the causes of the incidents can be related back to the early planning and design process. However, most initiatives to reduce these numbers and improve OHS in construction direct their attention towards the contractors. Thus, this research highlights the importance of implementing OHS considerations in planning and design and contributes with a practical framework and demonstration of how OHS can be integrated in the design of the construction projects and processes, parallel to considerations on budget and scheduled and possibly linked to discussion on quality, constructability, but also to agendas on sustainability etc.

The first stages study confirms that the architects and engineers only have a limited basic knowledge on OHS and that OHS-activities are not prioritized. OHS-activities are decoupled from the core activities in design and project planning. A structured and systematic approach to OHS in design and project planning is requested by the designers. The investigation further highlights that the approach must be integrated with existing design and engineering practices and may not be an additional stand-alone task. In a time with growing requirements on a number of subjects (energy, sustainability, IKT etc.) it is obviously important not to put an extra burden on the designers – and to compromise their mental health.

The integration of an OHS focus in the design phases demands for a comprehensive framework, since there are a lot of constraints to other parts of the processes. However, at the same time it is central, that the use of such an approach is not a burden to the projects participants. The OHS Log in the design phase is a dynamic, simple tool to assess, evaluate and manage OHS risks, and the testing and further development of this could be a vital element in the success of the overall framework. So far the interim testing shows promising results.

It also seems essential that changes to heighten the level of OHS must come both from society/legislation and from inside the companies. Participants in the initial study all referred to legislation as a driver. However, it is relevant to explain the non-OHS-professionals that legislation is only a minimum and to motivate the designers to strive for a higher level of OHS. Another task is to explain the architects and consultant engineers why they should be worried about safety in execution as an effect of their design. There continues to be an expectation that it is the contractor's responsibility – as long as the designers comply with legislation. Quality and sustainability are popular agendas under which OHS can be cultivated since these subjects are often an important part of the companies' social responsibility agenda to promote themselves in a competitive market. Another incentive to prioritize OHS in design is to visualize the costs of injuries.

The next part of the research project currently tests and evaluate the developed framework through interventions in the design process of a number of construction

projects. The research also investigates the effects in execution of the intervention process in design and planning.

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