Identifying Potential Health and Safety Risks at the Pre-Construction Stage

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Abstract

Previous researches have demonstrated that decisions made during the pre-construction stage have a big influence on the construction worker safety. This paper introduces a systematic approach for dealing with health and safety risks during the pre-construction stage. The developed methodology helps designers to calculate the safety-related performance of their residential construction designs, providing a consistent basis for comparisons between them. In order to avoid a typical shortcoming in the evaluation of health and safety risks, indicators are based on quantitative data available in the project documents. Significance limits are statistically obtained with the analysis of 25 new-start construction projects.

Keywords: construction hazards prevention through design, health and safety management, risk assessment, building, construction process.

1. Introduction

Compared to other industries, the construction sector is one of the most hazardous (Carter and Smith, 2006; Wang et al., 2006; Camino et al., 2008), killing approximately 350 employees per year in Spain (Ministerio de Trabajo e Inmigración, Subsecretaría de Trabajo y Asuntos Sociales, 2006). Construction accidents not only cause human tragedy, but also delay project progress, increase costs and damage the reputation of the contractors (Wang et al., 2006).

Designers, architects, engineers and contractors have an influence on the health and safety of building site employees (Gambatese and Hinze, 1999; Behm, 2005; Frijters and Swusste, 2008; Gambatese et al. 2008; Toole and Gambatese, 2008). Since the adoption of the Royal Decree 1627/1997 (transposition of Directive 92/57/EEC), Spanish building designers are legally required to consider health and safety in their designs. However, previous studies have shown that designers in general – not just in the construction industry- fall short of satisfying this obligation (Behm, 2005; Fadier and De la Garza, 2006; Frijters and Swuste, 2008). In addition, most contractors often neglect the implementation of their health and safety plans (Wang et al., 2006; Saurin et al., 2008).

During recent years, the concept of Construction Hazards Prevention through Design (CHPtD) has been widespread, in order to consider construction safety during the design phase. However, the literature has not yet addressed the technical principles underlying CHPtD in order to help designers better perform CHPtD (Toole and Gambatese, 2008). Additional tools and processes are needed in order to assist architects and design engineers with hazard recognition and design optimization (Gambatese, 2008).

2. Aim

The main objective of this paper is to develop a methodological framework to evaluate the safety-related performance of construction designs in order to reduce potential on-site health and safety risks.

The methodology facilitates the identification and quantification of health and safety risks related to the construction process of residential buildings during the design stage. Thus, health and safety risks related to the construction design are predicted before the building construction starts and therefore it will be possible to provide a range of on-site safety measures to avoid accidents at the construction site. The methodology is also able to provide the safety risk level of a building project, which can be used when comparing the safety performance of different construction companies and construction sites.

3. Development of the methodology

In order to calculate the safety risk level of a construction project, the first step is to identify specific health and safety risks related to the construction process. Assessing construction safety risks is the second step of this methodology, which includes: (1) development of indicators, (2) formulation of the significance limits and (3) determination of the overall safety risk level of a construction project.

3.1 Identification of safety risks related to the construction process

3.1.1 Process-oriented approach

The first step of the methodology is to identify safety risks related to the construction process. OHSAS 18001:2007 suggests using reports of incidents and accidents that have occurred in other organizations. In this case, guidance provided by the Occupational Accident Report Form of the Spanish National Institute of Safety and Hygiene at Work was used to initially identify general safety risks. However, safety risks coming from INSHT had to be customized to the construction process and for this reason an exhaustive preliminary analysis with a process-oriented approach was carried out. Safety risks provided by INSHT (Spanish National Institute of Safety and Hygiene at Work) were analysed for each construction process.

According to Gangolells et al. (2009a) and Gangolells et al. (2009b), construction processes initially considered were (1) earthworks, (2) foundations, (3) structures, (4) roofs, (5) partitions and closures, (6) impermeable membranes, (7) insulations, (8) coatings, (9) pavements and (10) door and window closures. Each of these main processes was separated into smaller process steps, so that finally a total of 219 stages were considered in this initial review.

3.1.2 Preliminary assessment of generic safety risks in each construction stage

According to OHSAS 18001:2007, risk is the combination of probability of occurrence and the severity of the injury or ill. In fact, consideration of risks in terms of the probability of their occurrence and the severity of their consequences provides the general rationale behind safety risks assessments (Carter and Smith, 2006). Probability (P) is defined as the likelihood of a hazard's potential being realized and initiating an incident or series of incidents that could result in harm or damage. Severity of consequences (C) is defined as the extent of harm or damage that could result from a hazard-related incident (Manuele, 2006). Both criteria are not dependant on the project, so they could be used in this early stage. Probability of Occurrence was defined ranging from improbable to very likely and Severity of Consequences was defined ranging from none to catastrophic. These grade scales were converted into a numerical scale so as to calculate the significance of a safety risk in a specific construction stage (Table 1).

The significance rating of a safety risk in a particular construction stage (SG_i) was obtained by multiplying these components of significance. A safety risk was considered to be significant for a particular construction stage if its SG_i was equal or greater than 3. The resultant matrix allowed us to distinguish potential safety risks for each construction stage. In order to make future assessments controllable and effective, most of construction risks were aggregated with the help of experts.

Table 1: Scoring system for Probability of Occurrence (P_i) and Severity of Consequences (S_i).

Probability of Occurrence (Pi)	***Severity of Consequences (S)***	***Score***
Improbable	*None*	*0*
Not very likely	*Minor*	*1*
Likely	*Major*	*2*
Very likely	*Catastrophic*	*3*

3.1.3 Health and safety risks related to the construction process

As a result of the process-oriented approach, 90 significant health and safety risks for construction activities were obtained and 22 categories of construction safety risks were proposed (Table 2).

3.2 Assessment of safety risks related to the construction process

Immediate causes of accidents include unsafe conditions and unsafe acts (Jannadi and Assaf, 1998; Fang et al., 2004). Unsafe conditions are physically conditions likely to produce an accident. Unsafe acts cannot be assessed during the pre-construction stage of the construction project and therefore they are not considered in this paper.

Unsafe conditions were evaluated by means of exposure, which assesses the frequency of occurrence of the hazard-event (Fine and Kinney, 1971) or the quantitative estimation of potentially hazardous situations to which workers are exposed during the construction process.

3.2.1 Determining indicators

In order to assess the risk exposure, specific indicators were developed. These indicators represent the variable that was being measured. They can be obtained from the information of construction project documents, since the proposed methodology is developed to assess health and safety risks during the design stage. Table 2 shows the corresponding indicators for each health and safety risk.

Table 2: Safety risks related to the construction process –obtained by means of a process-oriented approach- and corresponding safety indicators.

CONSTRUCTION SAFETY RISKS		***INDICATOR [P]***
FALLS BETWEEN DIFFERENT LEVELS		
FH-1	*During small demolition operations, earthworks and foundation work.*	*Total perimeter with a difference in floor level of more than 20 cm during the demolition, earthworks or foundation phases per m^2 of site occupation [m/m^2].*
FH-2	*During structural work.*	*Total perimeter of floors more than 20 cm high (from zero level) plus roof perimeter without boundary walls plus perimeter of holes measuring more than 0.40 m^2 per m^2 of floor area [m/m^2].*

CONSTRUCTION SAFETY RISKS		*INDICATOR [P]*
FH-3	*During roof work.*	*Roof perimeter without boundary walls plus perimeter of holes measuring more than 0.40 m^2 per m^2 of roof area [m/m^2].*
FH-4	*During work on facades, partition walls and vertical coatings.*	*Total area of partition walls plus total area of cladding on them (parging, plastering, tiling, painting, etc.) [m^2].*
FH-5	*During floor work.*	*Total perimeter of holes measuring more than 0.40 m^2 plus total perimeter of balconies without boundary walls per m^2 of floor area [m/m^2].*
FH-6	*During work on door and window closures.*	*Number of balconies without boundary walls and windows in the building [units].*
FH-7	*During work on false ceilings and ceiling coatings.*	*Total area of cladding of structural floors plus total area of false ceilings plus total area of cladding on them (parging, plastering, painting, etc.) [m^2].*
FALLS AT THE SAME LEVEL		
FS-1	*During small demolition operations and earthworks.*	*Site occupation [m^2].*
FS-2	*During reinforcement work.*	*Weight of reinforcing bars [kg].*
		Site occupation [m^2].
FS-3	*During roof work.*	*Total area of roof [m^2].*
FS-4	*During work on partition walls and vertical coatings.*	*Total area of partition walls plus total area of cladding on them (parging, plastering, tiling, painting, etc.) [m^2].*
INJURIES FROM FALLING OBJECTS DUE TO CRUMBLE OR COLLAPSE		
FOC-1	*During earthworks.*	*Volume of excavated and/or filled material [m^3].*
FOC-2	*Due to the use of in-situ concrete.*	*Volume of in-situ concrete [m^3].*
FOC-3	*During cladding work on facades.*	*Area of discontinuous cladding in facades [m^2].*
FOC-4	*During cladding work on partition walls.*	*Area of discontinuous cladding in partition walls [m^2].*
FOC-5	*During false ceiling work.*	*False ceiling area [m^2].*
INJURIES FROM FALLING OBJECTS DURING HANDLING		
FOH-1	*During materials and waste management operations.*	*Weight of structural floors, foundations, facades, partition walls, floors and roofs [kg].*
FOH-2	*During handling in prefabricated structure assembly.*	*In case of prefabricated structures: floor area [m^2].*
FOH-3	*During handling in cladding work.*	*Presence of heavy claddings.*
FOH-4	*During handling in work on door and window closures.*	*Size of window closures [m].*
INJURIES FROM OBJECTS FALLING FROM ABOVE		
OF-1	*During materials and waste management operations.*	*Weight of structural floors, foundations, facades, partition walls, floors and roofs per m^2 of floor area [kg/m^2].*

CONSTRUCTION SAFETY RISKS		INDICATOR [P]
OF-2	During earthworks.	Volume of excavated and/or filled material per m^2 of site occupation [m^3/m^2].
OF-3	During structural work.	Volume of in-situ concrete structures per m^2 of floor area [m^3/m^2].
OF-4	During roof work.	Total roof perimeter without boundary walls plus total perimeter of holes in the roof measuring more than 0.40 m^2 per m^2 of roof area [m/m^2].
OF-5	During work on facades and vertical coatings.	Total area of facades plus total area of cladding on them (parging, coating, painting, etc.) [m^2].
OF-6	During work on partition walls and vertical coatings.	Total area of partition walls plus total area of cladding on them (parging, plastering, tiling, painting, etc.) [m^2].
OF-7	During false ceiling work.	False ceiling area [m^2].
INJURIES FROM STEPPING ON OBJECTS		
SO-1	During small demolition operations.	Presence of foundations, retaining walls or evacuation elements from previous buildings to be demolished.
SO-2	During removal of garden elements.	Type of garden elements to be removed.
SO-3	Injuries from stepping on reinforcing bars, screws or nails.	In case of wood formwork or unknown type of formwork: volume of in-situ concrete in structures [m^3].
		Weight of reinforcing bars [kg].
INJURIES FROM HITTING STATIONARY OBJECTS		
HS-1	In provisional on-site facilities and storage areas.	Site occupation [m^2].
HS-2	During small demolition operations.	Presence of foundations, retaining walls or evacuation elements from previous buildings to be demolished.
HS-3	During removal of garden elements.	Type of garden elements to be removed.
HS-4	During structural work.	Volume of in-situ concrete structures per m^2 of floor area [m^3/m^2].
INJURIES FROM HITTING MOVING OBJECTS		
HM-1	During materials and waste management operations.	Weight of structural floors, foundations, facades, partition walls, floors and roofs per m^2 of floor area [kg/m^2].
HM-2	During earthworks.	Volume of excavated and/or filled material per m^2 of site occupation [m^3/m^2].
HM-3	During foundation work.	Volume of in-situ concrete in foundations per m^2 of site occupation [m^3/m^2].
HM-4	During structural work.	Volume of in-situ concrete structures per m^2 of floor area [m^3/m^2].
HM-5	During work on concrete foundations and floors.	Volume of in-situ concrete in concrete foundations and floors per m^2 of floor area [m^3/m^2].

CONSTRUCTION SAFETY RISKS		INDICATOR [P]
INJURIES FROM CUTS OR BLOWS FROM OBJECTS AND TOOLS		
CS-1	*During removal of garden elements.*	*Type of garden elements to be removed.*
CS-2	*During work on foundation and structure.*	*Volume of in-situ concrete in foundations and structures [m^3].*
CS-3	*During finishing work on roofs.*	*Total area of roof [m^2].*
CS-4	*During work on facades and partition walls.*	*Total area of facades and partition walls [m^2].*
CS-5	*During work on coatings or floors.*	*% of facing brick closure.*
		% of area with discontinuous ceramic and/or stone surfaces.
CS-6	*During work on false ceilings.*	*False ceiling area [m^2].*
INJURIES FROM PROJECTION OF FRAGMENTS AND PARTICLES		
FF-1	*In cutting operations.*	*% of facing brick closure.*
		Total area of ceramic partition walls [m^2].
		% of area with discontinuous ceramic and/or stone surfaces.
FF-2	*In concrete operations.*	*Volume of in-situ concrete in concrete foundations and floors [m^3].*
FF-3	*In spray-gun painting operations.*	*% of facade painted with spray gun.*
INJURIES FROM BECOMING CAUGHT IN OR BETWEEN OBJECTS		
CO-1	*During materials and waste management operations.*	*Weight[3] of structural floors, foundations, facades, partition walls, floors and roofs [kg].*
CO-2	*During small demolition operations.*	*Presence of foundations, retaining walls or evacuation elements from previous buildings to be demolished.*
CO-3	*During removal of garden elements.*	*Type of garden elements to be removed.*
CO-4	*During earthworks.*	*Volume of excavated and/or filled material [m^3].*
CO-5	*During work on piles, micro-piles and screen walls.*	*Presence of piles, micro-piles or screen walls.*
CO-6	*In forming and shoring operations.*	*Volume of in-situ concrete in structure [m^3].*
CO-7	*In operations with scaffoldings or working platforms.*	*Floor area [m^2].*
INJURIES FROM BECOMING CAUGHT IN DUMPED VEHICLES OR MACHINES		
CV-1	*During materials and waste management operations.*	*Weight of structural floors, foundations, facades, partition walls, floors and roofs per m^2 of floor area [kg/m^2].*
CV-2	*During earthworks.*	*Volume of excavated and/or filled material per m^2 of site occupation [m^3/m^2].*
CV-3	*During foundation work.*	*Volume of in-situ concrete in foundations per m^2 of site occupation [m^3/m^2].*
CV-4	*During structural work.*	*Type of auxiliary machinery used to assemble the*

CONSTRUCTION SAFETY RISKS		INDICATOR [P]
		structure.
CV-5	*During pavement work.*	*Volume of in-situ concrete in concrete foundations and floors per m^2 of floor area [m^3/m^2].*
OVERXERTION. BAD POSTURE OR REPETITIVE MOTION		
OX-1	*Injuries form overexertion, bad posture or repetitive motion.*	*All cases.*
INJURIES FROM EXPOSURE TO EXTREME TEMPERATURES		
ET-1	*Injuries from exposure to extreme temperatures.*	*Climate situation of the construction site.*
INJURIES FROM THERMAL CONTACTS		
TC-1	*Due to specific welding operations.*	*Type of structure.*
TC-2	*Due to joining waterproof membranes.*	*Type of joints used with waterproof membranes.*
INJURIES FROM ELECTRIC CONTACTS		
EC-1	*With active elements.*	*All cases.*
EC-2	*Due to breakage of underground electric power cables.*	*Presence of underground electric power cables.*
EC-3	*Due to contact with balling pumps.*	*Excavation level.*
EC-4	*Due to contacts with overhead electric power lines.*	*Presence of overhead electric power lines.*
INJURIES FROM EXPOSURE TO HARMFUL OR TOXIC SUBSTANCES		
EH-1	*During materials and waste management operations.*	*All cases.*
EH-2	*During specific welding operations.*	*Type of structure.*
EH-3	*Due to the use of concrete release agents at the construction site.*	*Use of concrete.*
EH-4	*Due to joining waterproof membranes.*	*Type of joints used with waterproof membranes.*
EH-5	*Due to the use of synthetic paints and varnishes.*	*% of synthetic paints and varnishes.*
EH-6	*In surface-polishing operations.*	*Presence of floor area made from natural wood or other materials that require polishing.*
INJURIES FROM CONTACT WITH CAUSTIC OR CORROSIVE SUBSTANCES		
CC-1	*During work on foundations and in-situ concrete structures.*	*Volume of in-situ concrete in foundations and structures [m^3].*
CC-2	*During work on brick closures and coatings.*	*Volume of mortar [m^3].*
CC-3	*During work on concrete foundations and floors.*	*Volume of in-situ concrete in concrete foundations and floors [m^3].*
INJURIES FROM EXPOSURE TO RADIATION		
ER-1	*Injuries from exposure to radiation due to specific welds.*	*Type of structure.*

CONSTRUCTION SAFETY RISKS		INDICATOR [P]
INJURIES FROM FIRES AND EXPLOSIONS		
AC-1	*Injuries from fires in areas for storing flammable and combustible substances.*	*Floor area [m^2].*
AC-2	*Injuries from breakage of underground pipes (electric power cables, telephone lines, water pipes, or liquid or gaseous hydrocarbon pipes).*	*Site occupation per m^2 of floor area [m^2/m^2].*
AC-3	*Breakage of receptacles with harmful substances. Storage tanks for dangerous products.*	*Floor area [m^2].*
AC-4	*Injuries from fires due to specific welds.*	*Type of structure.*
INJURIES FROM BEING HIT OR RUN OVER BY VEHICLES		
HV-1	*During material transport operations.*	*Weight of structural floors, foundations, facades, partition walls, floors and roofs per m^2 of site occupation [kg/m^2].*
HV-2	*During earthworks.*	*Volume of excavated and/or filled material per m^2 of site occupation [m^3/m^2].*
HV-3	*During foundation work.*	*Volume of in-situ concrete in foundations per m^2 of site occupation [m^3/m^2].*
HV-4	*In prefabricated structure assembly.*	*In case of prefabricated structure: floor area [m^2].*
INJURIES FROM TRAFFIC ACCIDENTS		
TA-1	*Injuries from external or internal traffic accidents.*	*Volume of excavated and/or filled material per m^2 of site occupation [m^3/m^2].*
		Weight of structural floors, foundations, facades, partition walls, floors and roofs per m^2 of site occupation [kg/m^2].
INJURIES FROM CONTACT WITH CHEMICAL AGENTS		
L-1	*Dust generation in activities involving construction machinery or transport.*	*Volume of excavated material per m^2 of floor area [m^3/m^2].*
L-2	*Dust generation in earthworks and stockpiles.*	*Volume of excavated material per m^2 of floor area [m^3/m^2].*
L-3	*Dust generation in activities with cutting operations.*	*% of facing brick closure.*
		% of the floor area having discontinuous ceramic and/or stone surfaces.
INJURIES FROM CONTACT WITH PHYSICAL AGENTS		
L-5	*Generation of noise and vibrations due to site activities.*	*Time of activity, use of special machinery (road roller, graders and compactors, etc.)*

In order to make the outcome of the process independent on the people who conduct the assessment, most of the developed indicators are objectively quantifiable. Indicators are expressed in absolute terms (when a particular health and safety risk is directly related to the volume of work), or in relative terms (measuring the density of hazards or as a percentage of a total amount).

So as to assess health and safety risks exposure (EX), a four-interval scale was developed. Numerical scores for risk exposure were assigned as shown in Table 3.

Table 3: Scoring system for risk exposure (EXj)

Risk exposure (EXj)	***Score***
No exposure	*0*
Low exposure	*1*
Significant exposure	*9*
High exposure	*25*

3.2.2 Obtaining significance limits

In order to establish numerical limits between the different exposure levels, 25 new-start construction projects were analysed. They ranged in size from a small block of two dwellings with a total floor area of 371 m^2 to a property development of 93 dwellings and a floor area of 12 681 m^2. They also ranged from three to seven levels above ground and from zero to two levels below ground.

So as to establish lower and upper limits for a significant exposure, a 68% interval confidence was calculated. Thus, if an indicator was lower than [μ-σ] for a particular construction project, the exposure to the corresponding safety risk was considered low. On the contrary, if it was higher than [μ+σ], the exposure to the corresponding risk was considered high. Indicators within [μ-σ, μ+σ] were considered as significant. Significance limits for each construction safety risk can be consulted on Gangolells et al. (2009b).

If after conducting the assessment, any construction safety risk is found to be unacceptable (EX>9), actions to eliminate or reduce that risk must be applied. In addition, if the documents of a construction project lack the information needed to make a satisfactory appraisal, high exposure is automatically assumed (EX_j=25).

3.3 Determining the overall health and safety risk level of a construction project

The methodology sets to assess the overall safety risk level of a construction project as shown in (1).

$$R = \sum_{j=1}^{n} EX_j \qquad (1)$$

Where R = overall safety risk level of a construction project; EX_j = exposure corresponding to a safety risk j.

Obviously, the construction project with the highest sum is the project with the lowest safety level.

4. Case studies

The methodology has been applied to the design process of a particular construction project: an isolated four-storey building with one underground car park floor. Lots of design decisions may have an effect on the final health and safety risk level, such as the choice between an in-situ concrete structure or a precast concrete structure, the choice of the roof type, the choice of the balconies, or even the size of the windows. Obviously, each design alternative tends to provide different benefits and to have different safety implications.

Analysing the choice between designing an in-situ concrete structure or a precast concrete structure, the methodology highlights that a precast concrete structure reduces risks FS-2 (falls between the same level during reinforcement work), FOC-2 (injuries from falling objects due to crumble or collapse due to use of in-situ concrete), OF-3 (injuries from objects falling from above during structural work), SO-3 (injuries from stepping on reinforcing bars, screws or nails), HS-4 (injuries from hitting stationary objects during structural work), HM-4 (injuries from hitting moving parts of machinery during structural work), CS-2 (injuries from cuts or blows from objects and tools during work on foundation and structure), CO-6 (injuries from becoming caught in or between objects in forming and shoring operations), EH-3 (injuries from exposure to harmful or toxic substances due to the use of concrete release agents at the construction site) and CC-1 (injuries from contact with caustic or corrosive substances during work on foundations and in-situ concrete structures). However, designing a precast concrete structure instead of an in-situ concrete structure causes two other safety risks: FOH-2 (injuries from falling objects during handling in prefabricated structure assembly) and HV-4 (injuries from being hit or run over by vehicles in prefabricated structure assembly). Thus, the safety risk level of designing an in-situ concrete structure was found to be 36, whereas the safety risk level of designing a precast concrete structure was found to be 18.

In the case of choosing a roof type (a trafficable roof with boundary walls or a slate gable roof with a slope of 45% and windows for ventilation), it was found that a trafficable roof with boundary walls reduces the construction safety risks FH-3 (falls between different levels during the roof work) and FS-3 (falls at the same level during roof work. Safety risks OF-4 (injuries from objects falling above during roof work) and CS-3 (injuries from cuts or blows from objects and tools during finishing work on roofs) are also reduced as a result of this alternative.

In any case, designers may assume different safety risk levels in the final design and implement on-site measures at the construction site in order to eliminate or reduce these risks.

5. Conclusions

This paper has presented a methodology for predicting and assessing health and safety risks associated with the construction of new residential buildings. In this way, the methodology is able to highlight how changing design decisions may affect the significance of a particular risk and, therefore, the overall safety risk level of the construction project. However, the methodology does not provide a list of design improvements because it could be seen by designers as an intrusion on their creative process.

This study represents a step forward to encourage smaller construction and design firms to adopt de CHPtD concept. The methodology not only ranks the significance of the safety risks in a specific construction design, but also compares the absolute importance of a particular safety risk in different construction projects. The methodology is especially worthwhile for those less-experienced designers who lack the skills and knowledge required to recognize hazards and develop optimal designs. Designers can compare different construction alternatives during the design phase and determine the corresponding safety risk level without their creative talents being restricted.

The strength of the methodology lies in the fact that it helps designers to explicitly consider construction worker safety during the design process. The developed methodology also highlights significant health and safety risks in advance. Thus, it will be possible to provide a range of on-site safety measures to avoid accidents at the construction site. Proactive hazard elimination is safer and more cost-effective than reactive hazard management.

Risk assessment has traditionally been a qualitative process and therefore subjective judgments often influence its accuracy. In this case, when assessing the safety risk level of a construction project using the suggested methodology, no subjective judgements have to be made, so that the outcome of the process is not dependant on the people conducting the assessment.

6. Further research

Further research is needed in order to consider contributing causes of accidents. Manageable factors for promoting workplace safety performance should be taken into account when a potential safety risk is assessed during the pre-construction stage. Moreover, and in order to better estimate the overall safety risk level of a construction design, future studies should explore the possibility of introducing a weighting system.

Besides these developments, further research is also needed to implement the methodology in a web-based information and knowledge management system with databases in it. Thus, it could be possible to reuse indicator calculations to the assessment of each design. In addition, data collected in previous assessments could be reused to refine the methodology, especially regarding the significance limits of health and safety risks.

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