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Systematic Methodology for Estimating the Social Dimension of Construction Projects—Assessing Health and Safety Risks Based on Project Budget Analysis

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Abstract

One of the major challenges in the construction sector involves achieving sustainability in all three of its dimensions: economic, social, and environmental. Economic and environmental assessments have already been unified, but social indicators are still excluded. In this line, it is important for a rapid introduction of sustainability indicators that the evaluations of its three dimensions are carried out simultaneously and without adding new training or a large workload to the project. In this work, it is proposed to use the definition of tasks in construction cost databases. These, due to their long tradition in the sector, have a clear definition of the contours of the problem and the inventory of resources. Therefore, based on this inventory that does not leave any unaccounted element, the evaluation of the social dimension is proposed through the use of the work units of the databases as an element of occupational risk assessment. The project cost and risk assessment are performed simultaneously in the construction of a social housing project in Andalusia, Spain. The costs of prevention measures represent 5% of the work units' costs and reduce the risk indicator by 65%.

Keywords: health and safety cost; risk assessment; occupational risks; social indicator; project budget

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1. Introduction

One important aspect of construction project sustainability is related to its social impact, and Health and Safety (H&S) risk indicators can be of importance since the sector is characterised by high accident and mortality rates on the work site. Two strategies can be defined to reduce the number of accidents and/or their severity: first, reduce the risks by means of prevention; and once the event occurs, reduce its impact through protection, following the model defined by Hollnagel [1]. Regarding prevention, in a review of the causes of construction accidents in Norway [2], 176 major accidents were studied, whereby it was found that immediate management and supervision and planning and risk control at different levels were of great importance, thereby underlining the need for risks to be addressed at various levels and by different actors in construction projects.

A study conducted in Korea [3] suggests classifying causes of accidents into direct and indirect groups. Direct causes are the difficulty of the work, the characteristics of the building, the urgency to finish the project, and the unsatisfactory response to unforeseen

situations on the construction site. Indirect causes are also important, such as safety culture, atmosphere, leadership, and management policies.

The direct aspects can be addressed by prevention through design (PtD). Addressing and minimising safety risks in construction from the initial phase of a project has generated interest in research since it was identified that 42% of fatality cases are related to the design [4]. But designers tend to avoid making decisions related to H&S, leaving it up to contractors during the construction phase.

In the United Kingdom, where PtD is integrated in their regulation, interviews were conducted with people from the sector who show changes in attitudes towards worker safety, in identifying who can have a positive impact, as well as better communication, knowledge transfer, and innovation in design [5]. Also in Australia, legislation includes PtD, and designers have responsibility for H&S issues of construction projects; therefore, H&S decisions are made early in the project development process [6]. In Spain, policies make it mandatory to comply with minimum H&S requirements for construction works. The obligation to prepare a H&S study on the work is established, in which it is necessary to plan the execution of the work, not only considering the occupational risks existing in the execution project, but also the inclusion of a budget [7]. However, despite being a legislative requirement in Spain, it has not permeated the attitude of those involved in the sector, in addition to the responsibility for prevention being delegated to those involved in the execution phase and removed from the design and planning phase.

In this line, the present work, in a novel way, proposes a methodology for the control and definition of risks from a systematised perspective, linked to the economic and environmental control of the project. The structure that integrates the construction cost databases, which are of extended use in the sector, has enabled the simultaneous evaluation of two dimensions of sustainability: economic and environmental [8,9]. In the present work, a link to the third dimension or social aspects is proposed through risk assessment and its reduction. Specifically, by focusing on the design and/or planning phase, a model is developed that analyses occupational risks in residential building construction. Therefore, the objective is to evaluate the prevention of occupational risks in the design and/or planning phase based on the budget and to define the necessary measures to minimise them. A new indicator is proposed for the evaluation of such risks.

1.1. Risk Identification Tools

The first step to reduce risks and hazards in the construction site is to identify them. For that, many tools have been introduced internationally. In the early 1990s, the Safety, Health, and Environmental Checklist for Contractors (Veiligheid gezondheid en milieu Checklist Aannemers), known as the VCA, was introduced in the Netherlands [10]. The VCA was employed in the training and certification of contractors in order to allow them to perform maintenance work and construction activities on construction sites of the chemical and oil industries. The mandatory certificate aimed to ensure an acceptable level of safety. Its introduction resulted in a drastic decrease in the number of accidents reported. Risk analysis and control measures form a strong combination in this model.

Another proposal for the evaluation and control of risks involves the construction toolbox safety index [11]. These authors present the design of a framework and protocol for risk management in the construction industry as a “toolbox”. This has a comprehensive and systematic approach for the evaluation and control of occupational risks. A qualitative risk assessment was generated, which determines a “band” of risk for a given project [12]. A total of 150 worksites were evaluated, and the Construction Site Risk Assessment Tool (CONSRAT) was developed. They propose the concept of “site risk”, which is defined as the risk associated with the entire work that is generated from the various elements that

individually affect the risk, since there may be potential risk synergies that can only be captured if the whole construction site constitutes the unit of analysis. But these solutions fall short and have limits that can intervene from the beginning in the conception of the project or project design, so that a notable change can occur in the sector.

1.2. Prevention Through Design

Some researchers have addressed the risks arising from innovations in building designs to make them environmentally sustainable. The authors of [13] defined a risk identification and assessment method that assesses risk in the Leadership in Energy and Environmental Design rating system (LEED). In the same line, the authors of [14] identified the safety impact of sustainable building design, where the injury rate is 9% higher than in non-LEED buildings, and similar design implications are explored by the authors of [15].

Designers, when they are aware of the risks on the construction site, are willing to address them during the design phase [16]. Tools have been developed to provide risk mitigation advice, recommend design alternatives, or facilitate site planning processes, but the designer's lack of knowledge of construction processes and limited availability to tools that help assess risk are barriers to implementing PtD [17]. Traditional PtD tools consist of risk assessment matrices, design guides, and database suggestions of lessons learned [18]. For example, the authors of [19] define a risk assessment method that helps designers assess the safety of residential building designs.

However, automation and many technological improvements, which have led to greater safety in other industries, have not had the same impact on the construction sector [10]. Therefore, other authors propose the use of Building Information Modelling (BIM) in the development of quantitative risk analysis to better support safety management [20]. Advances in BIM provide an opportunity to integrate computerisation and automation into risk prevention. Melzner et al. (2013) [21] and Qi et al. (2014) [22] developed BIM-based PtD verification tools to identify fall hazards and provide design alternatives through the case study of a three-story building. Zhang et al. (2013) [23] created a BIM-based tool that supports ontology-based automated occupational risk analysis in a case study of a masonry project. Yuan et al. (2019) [24] programmed a Revit plugin that helps designers verify security risks through a case study of a six-story building. Nnaji et al. (2023) [25] are also working on a BIM-based risk assessment approach that is integrated with a construction breakdown structure and site planning using a case study of a three-storey concrete building. Cortés-Pérez et al. (2020) [26] have developed a BIM-based method that integrates the Spanish H&S regulations in order to assess risks and to generate H&S plans.

Other authors propose the use of Building Information Modelling (BIM) in the development of quantitative risk analysis to better support safety management [20]. For example, risk libraries associated with construction scenarios allow threats to be automatically linked to BIM objects, following PtD approaches [27]. Advances in BIM provide an opportunity to integrate computerisation and automation into risk prevention [26] and have developed a BIM-based method that integrates the Spanish H&S regulations in order to assess risks and to generate H&S plans. Furthermore, works such as [28] propose the integration of Work Breakdown Structures (WBS) and Risk Breakdown Structures (RBS), stored in knowledge bases and linked with parametric BIM methods and risk repositories to facilitate visualisation and decision-making. The WBS and RBS structures are developed separately and then connected by rules; they are not from a single classification structure.

But what can really drive a change in BIM is a previous step: standardisation in the definition of the elements that generate risk and their link to BIM models. For this reason, it is necessary to continue developing a unification in the measurement of risk and implementation of prevention measures that facilitate decision-making by architects,

engineers, and builders in order to make the work site a safer environment, avoiding overlaps or unassessed risks. To this end, the breaking down of systems of construction work, which are already widely used in cost control, planning, or environmental assessment, can serve as a link for the integration of prevention from design. The problem boundaries already set in the construction cost definition or life cycle analysis can be useful to define risk assessment.

In this work, a more structural integration is proposed from an already-in-place classification of construction cost databases, which facilitates automation, scalability, and logical coherence for risk management in BIM environments. In our model, a single code stores all the information (costs, environmental, and social impacts), and the procedures are structured from the same hierarchy, sharing a single tree. It is the work unit or unit cost that has all the information stored.

2. Materials and Methods

A systematised methodology linked to economic control is proposed, which allows the control and definition of construction risks. The main source of information is the project budget, which contains information on the working hours of the staff and the type of work they perform. This information is used to define the work procedures and make it possible to be able to develop the social indicator. For better understanding, Figure 1 outlines the flow chart of the various stages of the methodology:

1. Project data: Analysis and identification of the different work units contained in the project budget. These work units provide information on worker hours and the type of work they perform (Figure 1).
2. Procedures of work units: The definition of the work procedures associated with the work units contained in the budget.
3. Risk assessment: For the assessment of accident risks, the holistic model proposed by Marrero et al. (2024) [29] is employed. This assessment provides the initial risk level of the work procedures, before incorporating corrective measures. Once the corrective measures are applied, the risk assessment is conducted again. (Figure 1).
4. Prevention Indicator (IP): The qualitative and quantitative evaluation conducted on the risks identified in their initial state and in their final state, after the application of the corrective measures, allows the development of the prevention indicator, which provides two results in parallel (Figure 1):
    - Risk reduction: This indicates the reduction in the level of risk that has been achieved with the incorporation of the corrective measures applied.
    - Cost (EUR): The determination of the economic cost of the corrective measures applied to achieve the reduction in the level of risk.

The methodology establishes a relationship between risk reduction and the cost increase due to implementation.

In the second part of Figure 1, the conceptual prototype for BIM integration is developed for the transfer of generated data and how it should be managed within the BIM environment. The first step will be to adapt the information contained in the cost database (bc3 format in Spain) files to the structure of the open IFC4 format and make it comply with the ISO 16739-1.2020 standard [30]. Initially, the attributes and properties necessary to incorporate non-native parameters related to the assessment of social sustainability will be identified, linking them to elements and resources of the BIM model, enabling their integration with the data associated with the external database. The created information structure will need to be tested to ensure its functionality and the efficiency of the developed workflow. Based on the previous conceptualisation, the information from the risk indicator file will be imported into a local database (SQL Server, MySQL, among others),

allowing for efficient data organisation and query. In addition, IFC parameters will be linked to the BIM model to store calculation results for the elements. As a final stage, an interactive representation of the model with colour scales locates the elements that generate the greatest social impacts. This functionality will allow users to make more efficient decisions to improve the project's social sustainability.

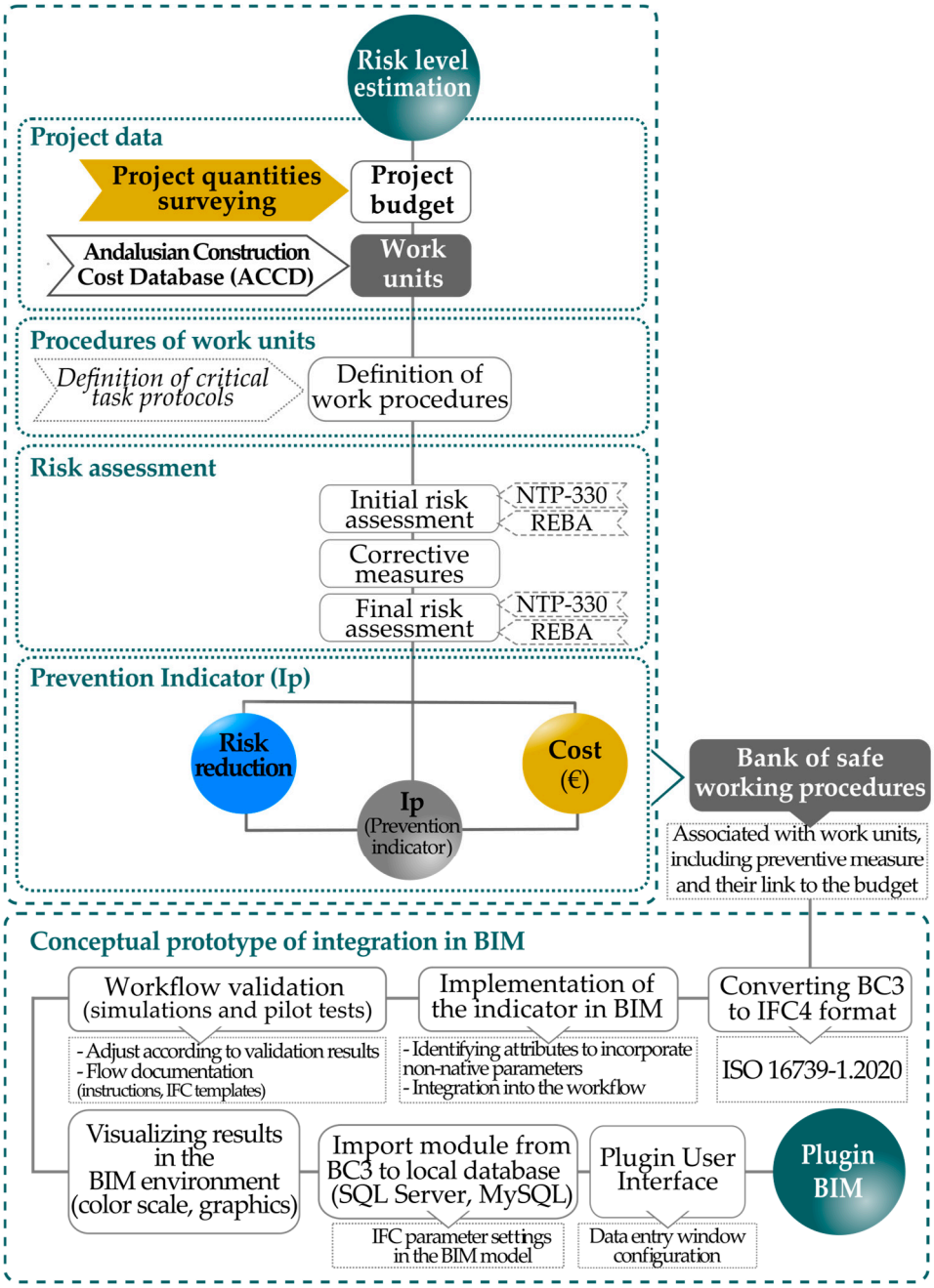


Figure 1. Methodological flowchart.

As for the boundaries of the system, it should be noted that this study is limited to collective and individual protection measures and the delimitation of spaces, including compliance with Spanish law (Ley_31/95, 1999) regarding the organisational and ergonomic activities necessary to prevent and/or minimise risks. The remaining H&S measures (hygiene and signalling of premises or training of workers) are not covered in this study because they cannot be linked to direct work units. It should be borne in mind that work equipment, especially machines, tools, provisional installations, and auxiliary means,

must comply with the provisions of Royal Decree 1215 of 1997 [31], which establishes the minimum H&S requirements for the use by workers of work equipment, as well as the rest of the mandatory standards associated with the equipment.

2.1. Classification of Construction Work

As a first step of the methodology, the contours of the problem are defined. To this end, the construction cost databases and their systematic classification of the work units are employed. This makes it possible to identify and define jobs, tasks, and their risks in projects. Construction cost databases are widely used in the construction sector [9], which enables, for example, the economic and environmental control of projects [32], which can be conducted throughout their life cycle [33]. Among the Spanish systems are ITEC in Catalonia [32], CYPE in Alicante [34], the Construction Cost Base of the Community of Madrid [35], PRECIOCENTRO [36], and the Andalusian Construction Cost Database (ACCD) in Andalusia [37]. Over 30 years ago, an agreement was reached in Spain regarding a common language and a simple and standardised format, called bc3 exchange format [38].

This research is based on the systematic classification of the ACCD [37]. Its management and classification system of work units is flexible and adaptable (an example is given in Figure 2A), which allows the incorporation of new work units with their indicators for the generation of models easily understood by technicians. The cost structure is created by virtue of a hierarchy that, starting from the lowest level, grows by joining the lower costs to form costs of a more complex nature. There are three large groups of costs, which, ordered from the lowest to the highest complexity, would be the following: basic costs distributed largely according to the three natures of machinery, labour, and materials; auxiliary costs formed by the union of these basic costs with the quantities appropriate to their typology and function, but which contain insufficient entities to be considered units of completed work, such as mortar or a masonry crew; and unit costs, which are formed by the union of basic costs and/or auxiliary costs (see Figure 2A). Each cost is identified with an alphanumeric code that enables an enormous number of combinations since it comprises twenty-six characters in the alphabetic blocks and ten in the numeric blocks. This leads to shorter codes with a great coding capacity. The letters, if carefully chosen, can provide additional intuitive information.

All costs are expressed as a unit of measurement with a measurement criterion, adjusted to the uses and tendencies of execution. The concepts described above together constitute the epigraph of a unit cost, resulting in all costs having an epigraph, which is different for each element of the system. The work units are organised in an ascending structure of sections, groups, subchapters, and chapters (Figure 2A).

2.2. Standardisation and Classification of Working Procedures

The procedures necessary for the work execution are defined for each work unit. At this point, it is essential to generate a codification of the procedures for their standardisation within the database. Each worker intervenes in one or more parts of the work unit that will be defined in the procedure codification. In the present work, an extension of the classification initiated at the unit cost level is proposed for the definition of the work procedures for work units in the ACCD.

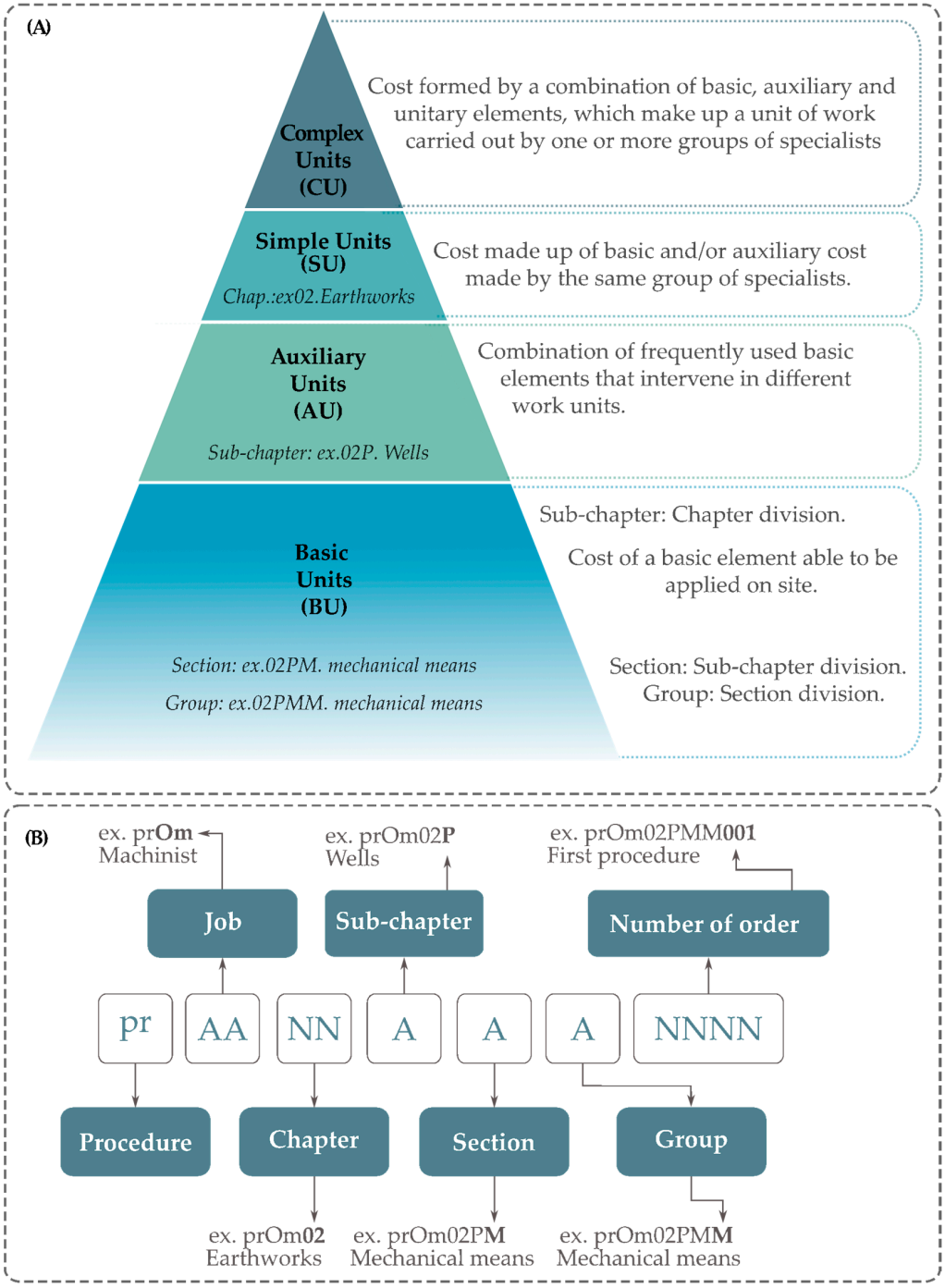


Figure 2. (**A**) Systematic classification ACCD. Example: 02PMM00012. Excavation of footings in soil of medium consistency, (**B**) schematic of the procedures coding. Example: prOm02PMM001. Digging a hole for the foundation concrete pad.

The codification can be seen in Figure 2B. The first two alphabetic characters are "pr" corresponding to a procedure type of code. In second place, two alphabetic symbols identify the type of job. In the present work, 13 different trades have been defined, for which their codes are Al (mason), Am (insulation fixer), At (roofing tiler), El (electrician), En (formwork), Es (plaster board placer), Fe (rebar worker), Fo (plumber), Ho (concrete mixer), Im (water-proofer), Om (machine operator), So (ceramic tiler), and Ye (plasterer). The coding is completed with the corresponding work unit code in the ACCD, followed by five blocks of alphanumeric characters. In the coding example in Figure 2B, the procedure code would be prOm02PMM001, where "pr" indicates that it corresponds to a procedure

code; "Om" means that the procedure's occupation is Machine Operator. From here, the code identifies the work unit to which it belongs within the ACCD, where the numerical value "02" indicates that it corresponds to the Land Conditioning chapter of the project, the letter (P) belongs to the Wells subchapter, and (MM) belongs to the By Mechanical Means group. And finally, the numerical value "001" indicates that it is in the first procedure of the series (Figure 2B).

For a better understanding, in addition to a detailed summary of equations and calculation methodology presented in Figure 3, each stage of the methodology is developed through an example: (1) project data, (2) procedures of work units, (3) risk assessment and (4) prevention indicator (Ip): risk reduction and cost (EUR).

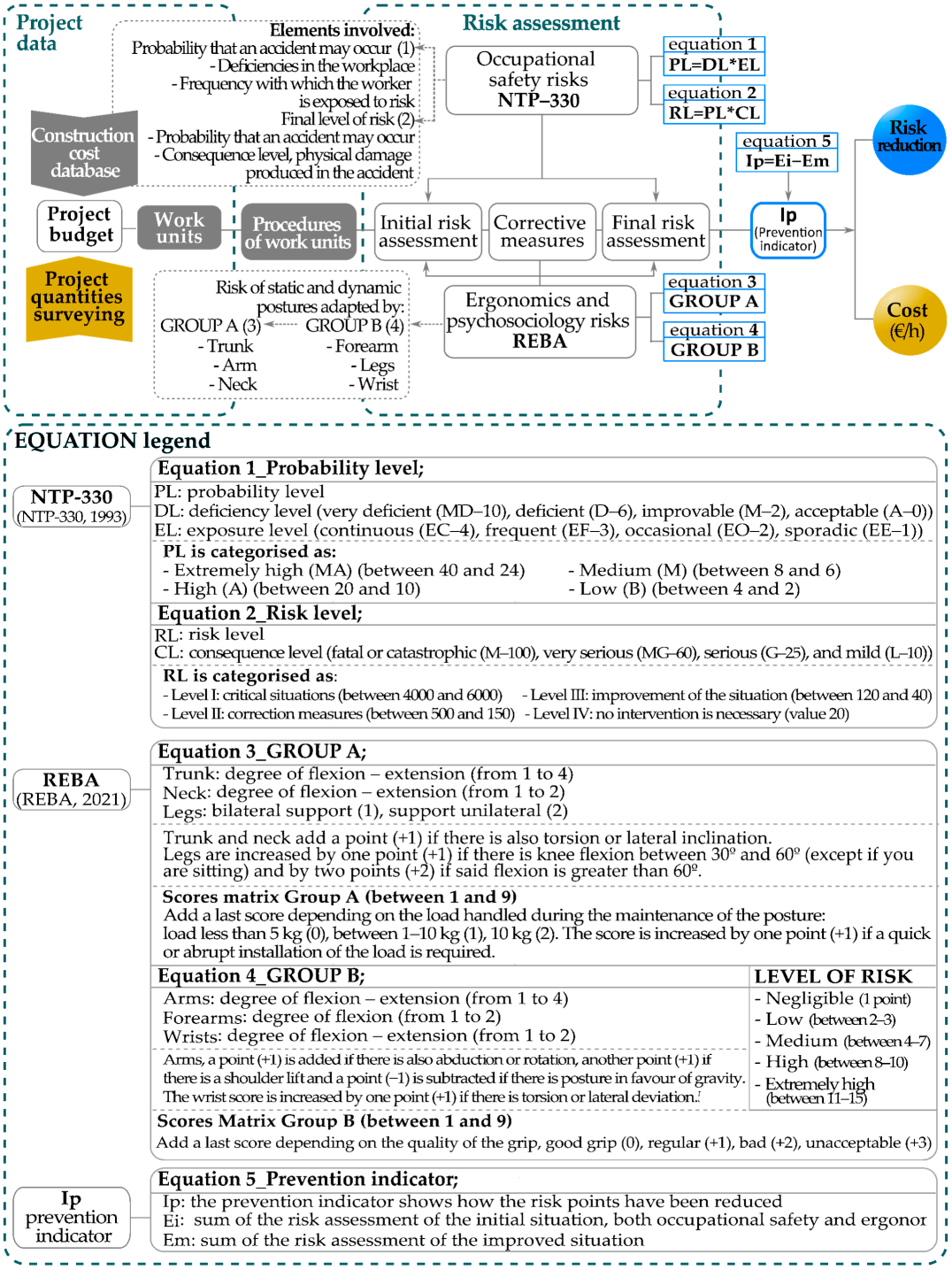


Figure 3. Summary of equations and calculation methodology for the prevention indicator.

2.3. Project Data

These work units provide information on worker hours and the type of activity they perform (Figure 3). For a better understanding, the methodology is described through an example: unit cost 02PMMM00002, which corresponds to the excavation of one cubic metre of hole for the foundation, in soil of medium consistency, using mechanical means at a maximum depth of 4 m (see Table 1). In its decomposition, the necessary labour is described, from which the jobs involved are derived. These jobs are then analysed, and their corresponding procedures are defined.

Table 1. Example of methodological development.

Project Data. Definition of Unit Cost				
02PMM00002	m^3			
Excavation of holes in earth of medium consistency conducted with mechanical means up to a maximum depth of 4 m, including extraction at the edges and profiling of bottom and sides.				
Measured volume in natural profile.				
Code	Concept	Quantity	Cost	Cost
TP00100	h SPECIAL LABOURER	0.120	18.90	2.27
ME00400	h BACKHOE	0.130	34.98	4.55
			Direct costs	6.82
			10.62% Indirect costs	0.72
Procedures of work units				
Code	Procedure			
prAl02PMM001	Profiling of bottom and sides			
prOm02PMM001	Hole digging with backhoe			
Division of the procedure into tasks/subtasks				
prAl02PMM001	Profiling of bottom and sides			
Starting situation				
- The hole has been dug by the backhoe machine and the earth has been transported. - The machine is located near the hole.				
Description of Level 1. Tasks and subtasks				
1. Checking the depth in the hole. 1.1. By means of a tape measure and as a reference set a pike that delimits the foundation concrete pad: it must be verified that the measurement is correct. 2. Hand profiling of the hole. 2.1. The slopes of the hole must be outlined by hand with a shovel to avoid any debris that could damage it. The earth at the edge of the excavation is shovelled.				
Final situation				
- Holes for foundation concrete pads are completed. - Earth collected at the edge of excavation.				
Identification of procedure risks (example of a procedure)				
prAl02PMM001	Profiling of bottom and sides			
Occupational safety risk				
Risk identification: 1. Risk of falling by the operator who is checking the excavation, caused by the detachment of the walls of the hole. 2. Risk of pushing the officer who is checking the excavation into the hole with the excavator shovel due to lack of control or machine operator error.				
Ergonomics risk				
Risk identification: 3. Risk of injury to the lower back from strained postures and repetitive movements when outlining the walls of the hole.				

2.4. Procedures of Work Units

The workstations involved in the work unit are analysed, and their corresponding procedures are defined. There are two jobs associated with the unit cost shown in the example (see Table 1): mason (Al) and machine operator (Om) (backhoe operator). The tasks to be executed have a starting and ending state with specific conditions. A total of 92 procedures are defined in the case study of a multifamily building construction.

2.5. Risk Assessment

The risk levels of the procedures in the most unfavourable situation are considered, which implies that collective or individual protection is not used, that the spaces have not been delimited, and organisational measures related to H&S are not taking place. The safety and ergonomic risks associated with the worst scenario are analysed (Table 1).

Once the risks have been defined, they are evaluated. First, the deficiencies that exist in the workplace are established. Then, it is necessary to define the probability that an accident may occur as well as the magnitude of the consequences of the accident. The NTP-330 method assesses occupational safety risks, and REBA assesses ergonomic risks. NTP 330 enables the level of the risks of the speciality of Safety at Work to be estimated [39]. In order to make this estimate, the first step is to identify the deficiencies that exist in the workplace. The probability that an accident may occur is included in the probability level (PL), which includes the deficiency level (DL) and the exposure level (EL). In order to calculate DL, the risk factor and to what degree it can cause an accident are determined. Four levels are contemplated: very deficient (MD-10), deficient (D-6), improvable (M-2), and acceptable (A-0). The EL calculates the frequency of exposure to the risk and is also classified into four levels of exposure, and their score are continuous (EC-4), frequent (EF-3), occasional (EO-2), and sporadic (EE-1). The probability level is expressed as the product of these two levels: PL = DL × EL. The PL is categorised as extremely high (MA) (between 40 and 24), high (A) (between 20 and 10), medium (M) (between 8 and 6), and low (B) (between 4 and 2). Another indicator that forms part of the calculation is the consequence level (CL), which has four levels and considers both physical and material damage as fatal or catastrophic (M-100), very serious (MG-60), serious (G-25), and mild (L-10). The risk level (RL) results from RL = PL × CL. Risk levels range from Level I (between 4000 and 6000) for critical situations in need of urgent correction to Level II (between 500 and 150) for situations requiring correction and control measures, Level III (between 120 and 40) for areas of possible improvement of the situation if possible, and Level IV (value 20) to indicate that no intervention is necessary (see Figure 3).

The second method employed is REBA (Rapid Entire Body Assessment), which enables Ergonomics and Psychosociology risks from work-related bodily disorders to be estimated. The method enables the analysis of the positions taken by the upper limbs of the body (arm, forearm, wrist), trunk, neck, and legs. In order to develop the method, its authors, supported by a team of ergonomists, physiotherapists, occupational therapists, and nurses, assessed around 600 working postures [40]. Work tasks with variations in load and movements were analysed. This study was carried out by applying several previously developed methods, such as the Niosh equation [41], the Effort Perception Scale [42], the OWAS method [43], the BPD [44], and the RULA method [45]. To this end, REBA evaluates the risk of static and dynamic postures adopted by arm, forearm, and wrist (group A) and by trunk, neck, and legs (group B) [46]. The score of group A begins with the position of the trunk, depending on the degree of flexion–extension, and it is scored from 1 to 4. The neck is scored from 1 to 2 depending on the degree of flexion–extension of the neck from two positions. Both trunk and neck add a point (+1) if there is also torsion or lateral inclination. Thirdly, the leg position score is 1 if there is bilateral support and 2 if the

support is unilateral, light, or of an unstable posture. The leg score is increased by one point (+1) if there is knee flexion between 30° and 60° (except when sitting) and by two points (+2) if said flexion is greater than 60°. With these scores, a matrix scores group A (between 1 and 9), to which we must add a last score depending on the load handled during the maintenance of the posture: a load less than 5 kg (0), between 1 and 10 kg (1), or greater than 10 kg (2). The score is increased by one point (+1) if a quick or abrupt installation of the load is required. The score of group B begins with the position of the arms, which depends on the degree of flexion–extension, and this is scored from 1 to 4. A point (+1) is added if there is also abduction or rotation, another point (+1) is added if there is a shoulder lift, and a point (−1) is subtracted if there is support or posture in favour of gravity. The forearms, depending on the degree of flexion, are scored from 1 to 2. The wrists are scored from 1 to 2 depending on the degree of flexion–extension. The wrist score is increased by one point (+1) if there is torsion or lateral deviation. With these scores, a matrix generates the score of group B (between 1 and 9) and adds a last score depending on the quality of the grip: good grip (0), regular (+1), bad (+2), and unacceptable (+3). After obtaining the scores of groups A and B, the score is obtained in the matrix, which defines the risk level (RL) (between 1 and 12). To this score, a point (+1) must be added in the following situations: if one or more parts of the body remain static, if there are repetitive movements, and if important postural changes are made. Finally, with this score, the level of risk is defined in the following ranges: 1 point (negligible), between 2 and 3 (low), between 4 and 7 (medium), between 8 and 10 (high), and between 11 and 15 (extremely high) (see Table 2).

Table 2. Example of initial risk assessment.

02PMM00002	m^3									
Code	Procedure									
prAl02PMM001	Profiling of bottom and sides									
Safety at work	Risk number	Probability (P)	Consequence (C)	PXC	Initial assessment		Ergonomics	Risk number	Initial assessment	
	1	24	100	2400	I	4		3	A-3	3
	2	24	100	2400	I	4				
				Σ safety hazards at work		8		Σ ergonomic risks		3
								Final summary		11

Table 2 shows an example of how the initial risk assessment is carried out using both methods of the prAl02PMM001 procedure: bottom and side profiling. The risk indicator is calculated for an excavation of 333.59 $m^{3,}$ which determines LE, that is, the frequency with which the operator is subjected to risk. To obtain the values for the levels of risk for safety at work and ergonomics, the NTP-330 method and the REBA method have been applied, respectively. The tables and matrices necessary to obtain partial values for obtaining the risk levels can be consulted in the official documents published for the application of both methods [39,46]. In order to add the results of the risk levels (RL) of the NTP-330 method (uses Roman numerals from I to IV) and the REBA (uses numbers), it is necessary to generate a numerical equivalence to the risk levels of the NTP-330. I to IV correspond to the values 4 to 1, respectively. This makes both methods work in a range that goes from 1 to 4. Also, additional tables are employed that are in the annexe example, Table A2.

Once the initial risk assessment has been carried out, preventative measures are taken to eliminate or minimise risks in the initial assessment. These are classified according to the factors they influence: technical, organisational, or environmental (Table 3). The risk assessment of the procedure is subsequently conducted by considering the measures adopted (see Table 4).

Table 3. Example of preventative measures taken.

02PMM00002	m^3		
Code	Procedure		
prAl02PMM001	Profiling of bottom and sides		
Corrected situation			
Technical factor	Auxiliary means	-	Ladder
	Personal protection	-	Safety helmet - Reflective vest - Non-slip safety boots - Safety gloves - Lumbar dorsum girdles
	Collective protection	---	
	Signalling and delimitation of spaces	-	Delimitation of passage zone - Perimeter dimensioning
Organisational factor		-	Cleaning of the faces of the hole excavated - 5 min break every 30 min
Environmental factor		-	Running the task at more suitable temperatures

Table 4. Example of risk assessment of the improved situation.

02PMM00002	m^3						
Code	Procedure						
prAl02PMM001	Profiling of bottom and sides						
	Improved situation						
Safety at work	Risk	Corrected assessment		Ergonomics	Risk	Corrected assessment	
	1	IV	1		3	M-2	2
	2	IV	1				
	Σ safety hazards at work		2		Σ ergonomic risks		2
					Final summary		4

2.6. Prevention Indicator (Ip)

The prevention indicator (Figure 3) is obtained from the quantitative assessment of the risks identified in their initial and final state, or before and after the incorporation of corrective measures. The prevention indicator (Ip) shows how the risk level has been reduced (Figure 3), where Ei is the sum of the initial risk assessment, both for occupational safety and ergonomic risk, and Em is the sum of the risk assessment of the final situation (with the corrective measures incorporated) (Figure 3, definition of the equation legend: prevention indicator). With the data provided by the indicator, it is possible to determine the reduction in risk levels that has been achieved with the incorporation of the corrective measures applied, as well as the economic cost (EUR) of the corrective measures applied to achieve the reduction in the risk level.

The results of the risk assessment of the initial situation are Ei = 11 (see Table 2). Once the preventative measures are adopted, the improved situation is Em = 4 (see Table 4), which represents a 67% reduction.

H&S costs can be determined indirectly in the same way as the jobs for each work procedure. According to the structure of the ACCD, the direct costs for the adoption of

the measures of each work unit are assigned by adding the costs of all its procedures. In the total construction budget, all prevention-related costs are grouped within Chapter 19 of Prevention and safety activities (for example, the unit cost of the worker's helmet is measured in euros per helmet unit).

The classification of the ACCD (see Figure 2A) can be employed for an AI-driven methodology. The codes' numbers and letters can be employed for the definition of the construction tasks and the risk evaluation, as shown in Figure 2B. A tree has been added to show a possible expansion of the present work (see Figure 4). Some work units of the ACCD are used to illustrate how the same procedure could be associated with others, specifically, procedure PrOm02PMM001. The excavation of a hole for the foundation footings can be associated with the units listed in Figure 4, since these are excavations in which only the type or consistency of the soil varies. Once the database is completed, artificial intelligence can be applied to identify patterns, as in [47], or predictive models in time series can be used, as in [48].

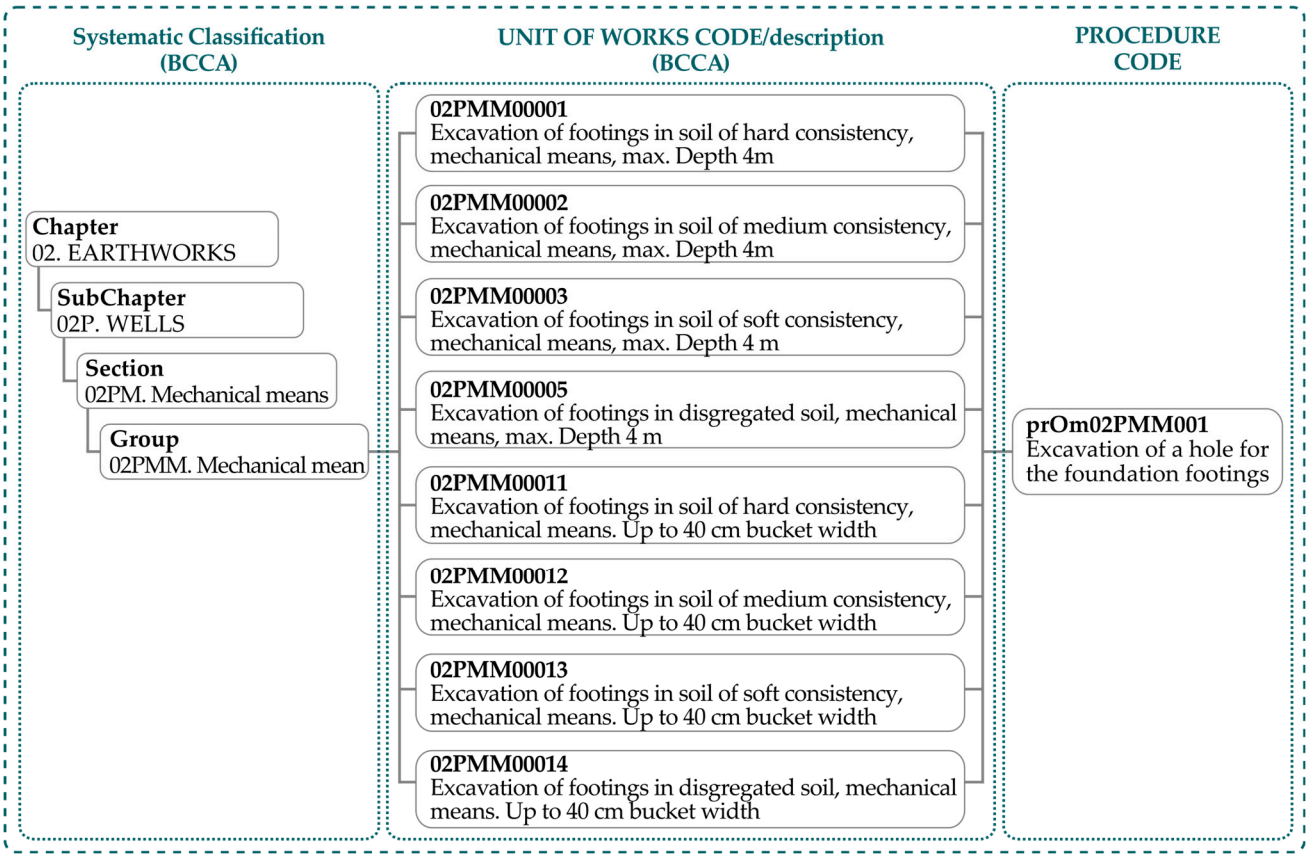


Figure 4. Work units with coding starting with 02PMM can adhere to one common procedure: pr0m02PMM001.

The developed model offers innovative potential for visualising, anticipating, and managing risks more effectively and comprehensively, especially in the design and planning phases. However, it does not replace a management system such as that proposed by ISO 45001 [49], which establishes the organisational, regulatory, and procedural requirements for a solid preventive culture. The developed model is intended to be used as a technical support tool within an ISO 45001 system, integrating advanced visualisation with structured organisational management.

3. Case Study

The case study consists of the construction of a housing project representative of the most commonly built typologies in Spain. Housing construction accounts for 85% of all new construction, of which four-story multi-family buildings comprise 32% [50]. The case study building is located on a rectangular plot of 200 m^2. The floor area is 625 m^2, built on three floors above ground level, and with an installation area on the roof. It contains a total of 6 dwellings (two per floor). The foundation is of reinforced concrete footings, and the structure combines a sanitary slab on the ground floor, pillars of 30 × 30 cm, and a bidirectional slab on other floors. The exterior enclosure is formed by a brick wall, one foot in thickness. The interior divisions between houses are executed with one-foot ceramic bricks of the same characteristics as the exterior enclosure, and the interior partitions between rooms of the houses are 4 cm thick performed with ceramic bricks. As for the coatings, the floors are terrazzo tiles of 40 × 40 cm with medium-grain marble, the ceilings are trimmed and plastered, except in the kitchens and bathrooms, whose ceilings have plasterboard suspended from metal elements. Likewise, the walls are trimmed and plastered, except in kitchens and bathrooms, which are tiled with 15 × 30 cm glazed ceramic tiles. In the exterior, the walls are finished with a monolayer coating. The concrete slab roof is flat and non-passable, and consists of a top layer of mortar, modified bitumen membrane, a steam diffuser layer, an extruded polystyrene insulation panel, anti-puncture polypropylene fabric, and a 5 cm thick protection layer with rolled aggregate.

For simplification, some construction units have been excluded from the analysis, such as in Chapter 08. Installations only include electrical, water supply, and drainage installations. Chapters that are completely excluded are Chapter 11, which refers to the work conducted outside the building, such as gardening, pavements, roads, and play areas; Chapter 12, Quality assurance; Chapter 17, Waste management; and Chapter 19, Safety. And overhead costs and taxes are not part of the total budget. Finally, the project is formed by 58 unit costs or work units, which need the definition of 92 procedures. All the preventative measures taken in the case study are summarised per chapter in Appendix A (Appendix A.1. Table A1). The present work consists of a first step, where only this list of work units has been evaluated so far. Those were chosen because they are representative of the main activities in a dwelling construction project, as set out in previous points. The most representative project in the region is a multifamily housing with three floors [9,29,50].

4. Results and Discussion

The project's original risk level, previous to any safety measure, and the improved risk level are calculated for the 92 procedures identified in the project. Appendix A (Appendix A.1, Table A2) summarises the risk reduction per work unit of the project. Table 5 shows the costs per floor area of the construction chapters and the reduction in the risk indicator. In order to indicate which work units are more important, a range in colours is established with red for the elements that are three times the standard deviation away from the mean, two times is dark green, and one time is bright yellow (see Table A3).

Another strong aspect of the present methodology is that it automatically includes H&S-related costs. Once risk assessment can be integrated into work breakdown systems, related costs are also part of the analysis, which becomes an additional tool to control prevention measures being included in projects. Ahn et al. (2021) [3] suggest that in order to ensure that occupational H&S measures are properly implemented, their needs should be included in the construction project budget since their implementation is not free, and that this can be achieved by making it a permanent feature in the project's budget. They also identified that the management cost of H&S is commonly determined as a percentage of the total budget. Subsequently, when the H&S management plan is established onsite, which

corresponds to the requirements and regulations in the country, the cost of management is usually higher than in the first estimate. These researchers have found that the cost estimation methods of H&S measures fail to reflect the characteristics of the project. In Malaysia, where accident and injury statistics in the construction industry were among the highest compared to other sectors, insufficient economic resources are allocated to H&S management, ranging from 0.15% to 1.08%, with an average of 0.41% [51]. Feng (2013) [52] proposes that H&S measures, such as staffing, equipment and safety facilities, mandatory training, internal safety training, safety inspections and meetings, safety incentives and promotions, and safety innovation, all be included in the cost estimate. The total proportion of investment in safety ranged from 1.62% to 3%. Gurcanli et al. (2015) [53] examined blueprints, quantity surveying, etc., of 25 specific buildings in Istanbul and established the ratio between safety cost and total construction cost to be 1.9%. In Spain, Ibarrondo-Dávila et al. (2015) [54] developed and implemented a model to analyse and control the safety costs applied to two construction projects; in this case, the percentages were higher, at 2% and 4.5%. In the present analysis, the cost increase is 5.12%, close to the other study in Spain.

Table 5. Costs per m^2 of floor area and the risk reduction per chapter.

	Cost (EUR/m²)		**Risk Indicator (Ip/m²)**		**Cost per Risk (EUR/Ip) (EUR/Reduction)**
Chapters	**Initial**	**Corrected**	**Initial**	**Corrected**	
02. Earthworks	0.53	0.86	0.024	0.008	0.03
03. Foundation	11.57	12.48	0.078	0.03	0.03
04. Sewer system	7.89	8.6	0.066	0.042	0.05
05. Structures	83.02	96.06	0.496	0.126	0.06
06. Masonry	71.43	72.88	0.072	0.022	0.05
07. Roof	20.59	21.34	0.219	0.069	0.01
08. Installations	59.46	60.55	0.741	0.253	0
09. Insulation	27.78	28.01	0.08	0.037	0.01
10. Finishes	105.86	107.25	0.379	0.158	0.01
Total	388.14	408.02	2.155	0.746	0.24
Increased cost/decreased risk in the project per m^2					
Total	(EUR/m^2)	%	Total	(Ip/m^2)	%
Cost increase	19.89	5.12	Ip reduction	1.41	65.4

The risk level of the project is reduced by 65%. The structures chapter stands out with the greatest reduction of 75%, followed by the masonry and roof chapters, with 69% each (see Figure 5). Since these are the chapters that present a considerable risk of falling from a height, the protection and preventative measures achieve a substantial reduction. These major risks coincide with those found in Spain by Camino-Lopez [55], where scaffolding, ladders, and cranes—elements used in the construction of structures, masonry, and roofs—caused most accidents.

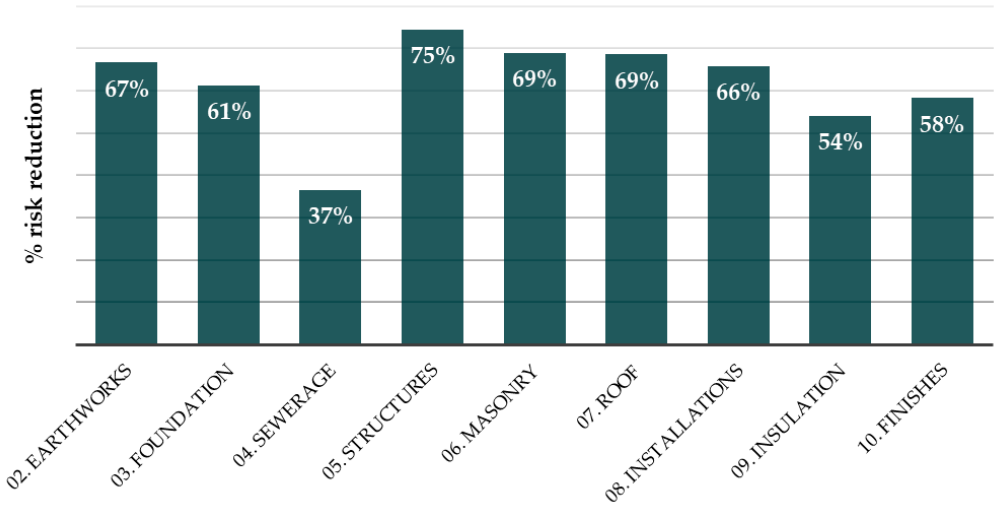


Figure 5. Risk reduction percentage by chapters.

At the level of unit costs, the greatest risk reduction is 80%, in 05FUA00005, corresponding to the incorporation of a concrete slab with self-resistant beams. This work unit has four procedures, of which the following stand out: PrAl05FUA002, which affects the mason during the placement of the beams and vaults; and prFe05FUA003, which affects the rebar placer during the placement of the concrete reinforcements, both with a risk reduction of 83% (Figure 6). This quantitative analysis enables the level of risk of the project to be related to the investment made to reduce the risk (Figure 7). It can be observed that in Chapter 02 Earthworks, the values of investment and risk reduction are very close in the graph (Figure 7). Since the measures adopted have not entailed a high cost, nor have a high-risk reduction, the chapter also has a low risk level. In the case of Chapter 05 Structures, there is a high initial risk level due to the possibility of falling from a height. In this case, we can observe how the investment in protection measures is the highest of all chapters, but it also has a significant risk reduction achieved (Figure 7).

At a qualitative level, the proposed model enables the analysis to be conducted in the design phase of the risks to which workers are exposed according to their job. And at the same time, it is possible to obtain a quantitative assessment of the risk through the indicator for all the work units included in the project chapters. This allows the substitution of work units that generate an important level of risk during the project design phase. Table 6 shows two examples of work in which changing the construction element for an alternative solution (in bold in Table 6) reduces risks. Specifically, it is reduced by 6% in the case of changing the reticular slab by a concrete slab with self-resistant beams, the operator is prevented from repeatedly subjecting himself to the risk associated with removing the coffers. Another element is reduced by 86% by changing the brick enclosure from one that needs a single layer coating to an enclosure made of exposed brick, since the work unit for the execution of the single layer is directly eliminated and, therefore, the risks. In addition, the model makes it possible to check whether the protective measures included in the H&S budget correspond to the risks of its construction units. By studying several projects, the influential factors and cost can be optimised in order to achieve maximum safety, as in [56].

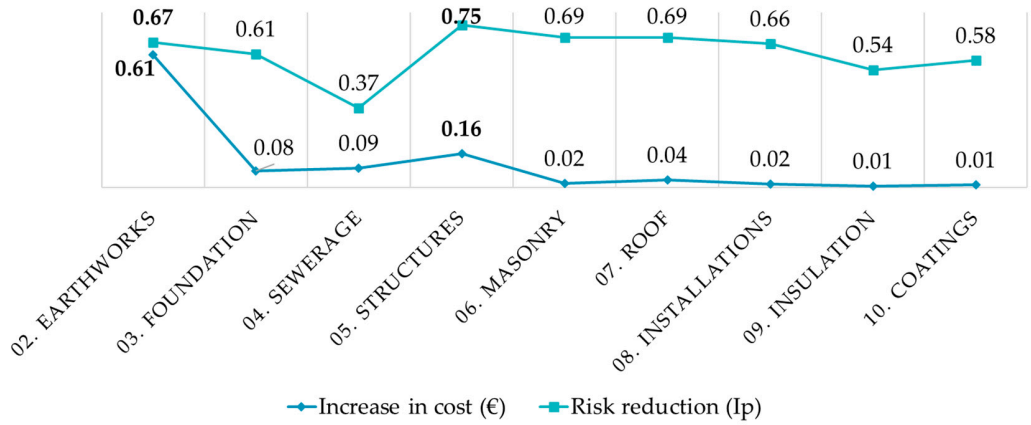


Figure 6. Risk reduction at unit cost level.

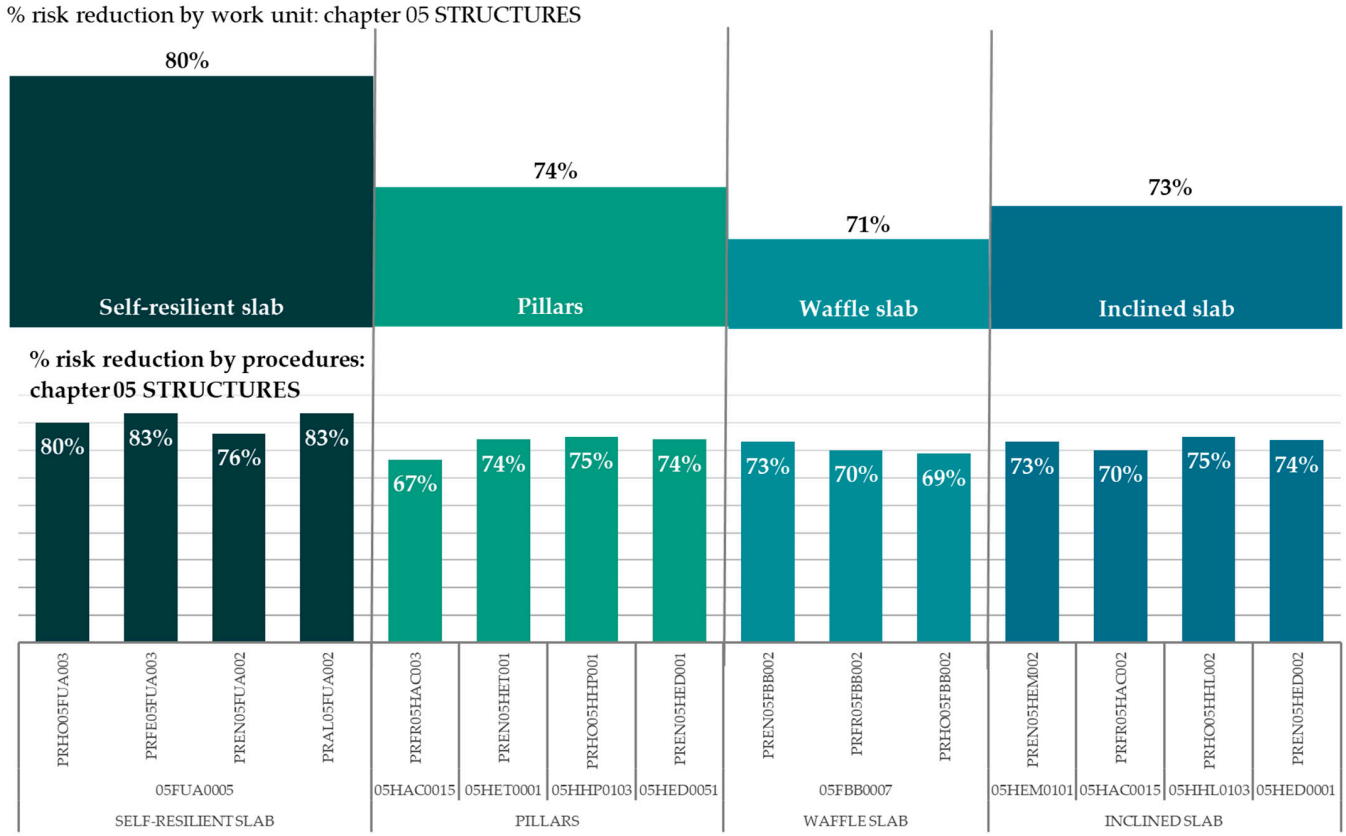


Figure 7. Relation between percentage of risk reduction and cost of the measure.

Table 6. Alternative constructive solutions (in bold).

Code	Unit	Concept	Q	Cost (EUR)	H&S Risks
05FBB00037	m^2	Reticular slabs with recoverable coffers	594.28	26,534.60	66
05FUA00005	**m^2**	**Concrete slab with self-resistant beams**	**594.28**	**32,822.08**	**62**
		% improvement impact		**−19%**	**+6%**
10CWW00006 + 06LPM00001	m^2	Single layer coating with aggregates on brick + wall of small drills bricks	656.235	23,197.91	90
			621.4	22,208.84	15
06LPM00002	**m^2**	**Wall of small drills bricks with exposed face**	656.235	31,715.80	15
		% improvement impact		**−30%**	**−86%**

The main weakness of the present methodology is that it fails to consider any training of the workers (mandatory in Spanish legislation) since they are not connected to individual work units, and neither does this methodology take the preventative culture on the worksite into consideration since its effects need an independent model in order to assess its impact on H&S. Other aspects that have been excluded from this model and should be added in future work include monitoring, individual characteristics of the site condition, such as attitude/motivation, age/experience, and contractor size or rate of subcontracting, which are also influential on the safety level [2]. Similarly, other aspects that should be included are unsafe behaviours and accidents, such as safety climate/culture, information, and project management [57]. Furthermore, accidents are usually multicausal, resulting from a combination of overlapping factors [58]. Other authors have identified that the effect of basic safety investments on performance differs across different projects. The implication of their findings is that greater protection and a safer environment do not always produce better safety performance without improved safety culture [52].

Even though, as said in the discussion, there are elements that are missing in the analysis, the main focus of the work is to improve the H&S from the design stage by adding information to the already existing packages of information contained in the project work units, i.e., cost and environmental impacts, in order to improve from early stages of the project, the H&S assessment in parallel to other indicators. Because the work units are the vector of information, they can only contain part of the information related to H&S in the construction site, then not all the risks and their interconnection are represented. But the present work can be included as part of the information in a broader analysis.

Another aspect yet to be included is the evaluation of the opportunity cost of the investments in safety aimed at mitigating and preventing those serious accidents that can lead to financial losses and deaths [59], and the evaluation of the optimisation of such investments [56,60].

5. Conclusions

The social impact assessment of construction projects is the sustainability dimension less addressed. The present work shows that it is possible to define a methodology that can be implemented as part of construction cost databases, which are generic and commonly used. The proposed methodology allows the automation of the analysis of occupational risk prevention in the project phase. To this end, based on the information held in the project budget, which follows the structure of a cost database, the work procedures are established for all work units that are part of the project. These procedures are accompanied by their risk assessment and the measures necessary for the minimisation of their risk. Although it is impossible to eliminate every risk of the work procedures, the necessary measures in each group of tasks can clearly be defined.

At a qualitative level, it can be concluded that the model enables the automation of the analysis of the risks to which the workforce is exposed to be analysed according to their tasks, while, at the same time, calculates a quantitative assessment of the risk. Furthermore, it can be verified whether the protective measures incorporated in H&S budgets correspond to the risks of its construction units. The database of procedures, risks, and measures can evolve in a structured way with the evaluation of new projects.

The proposed quantitative analysis includes the study of the level of risk of a specific project, and the valuation of the economic investment necessary for the elimination or minimisation of such risk.

The methodology proposed that each time a new work unit is defined it can be accompanied in an automated manner by the risk assessment and the minimum prevention and protection measures, this will constitute an information package that can be attached

to the economic and environmental assessments by employing a unified structure. The model can help companies define work procedures and conduct initial risk assessments in order to both complete their occupational risk prevention plans and correctly plan operator training courses.

It has been deduced that an automated construction procedures database is necessary that includes all the costs of the Andalusia Construction Cost Database so that every activity defined in the budget can be evaluated in terms of risk. This database can also be supplemented with procedures for diverse types of buildings. Procedures can also be managed by using BIM and by linking them to BIM objects of work units, and via their corresponding procedures and risks.

As future lines of research concerning the work undertaken herein, in order to help managers make better decisions about H&S investments, by getting a better idea of how effective certain budget allocations will be at lowering risks, decision trees and random forests can be used to predict campaign ROI, as in the work by Hayadi and Emary (2024) [61]. Also, Advance modelling techniques could potentially be used to create future models that combine budget data with elements that affect real on-site H&S resilience as in the work by Hery and Widjaja, A. E. (2024) [62]. The work methodology can also be combined with time-based patterns in H&S incident reports or construction site paperwork, like Buchdadi and Al-Rawahna (2025) [63] conducted for crime patterns, which could show important risk trend and patterns in H&S incident reports or construction site paperwork, like in Dewi, D. A., and Kurniawan, T. B. (2025) [64].

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Appendix A.1

Table A1. Prevention measures applied in the case study. Catalogued per work chapter and per typology.

Prevention Measures per Chapter		Prevention Measures per Type
02. Earthworks	**06. Masonry**	**Collective protection**
- Non-slip safety boots	- Placement of nets in façade openings	- Free-edge guardrail
- Non-slip safety boots	- Placement of nets in façade openings	- Railing on forged formwork
- Safety helmet	- Nets in enclosure voids	- Railing on sloping slab formwork

Table A1. *Cont.*

Prevention Measures per Chapter				Prevention Measures per Type
-	Reflective vest	-	Work area delimitation	- Railing on slab
-	Dorsal-lumbar girdles	-	Non-slip safety boots	- Railing on inclined slab
-	Safety gloves	-	Helmet	- Horizontal forged hollow railings
-	Perimeter dimensioning	-	Dorsal-lumbar girdle	- Placement of railings on the edge of excavation
-	Delimitation of passage zones	-	Protective glasses	- Placement of nets in façade openings
		-	Safety gloves	- Placement of rebar protection mushroom caps
		-	Dust mask	- Extinguisher
				- Under-forged nets
				- Nets in façade openings
				- Marquee
03. Foundation		**07. Roofs**		**Individual Protection**
-	Placement of rebar protection mushroom caps	-	Extinguisher	- Noise damper
-	Non-slip safety boots	-	Marquee	- Safety harness
-	Wellies and safety boots	-	Safety harness	- Non-slip safety boots
-	Safety helmet	-	Non-slip safety boots	- Wellies
-	Reflective vest	-	Helmet	- Wellies and safety boots
-	Dorsal-lumbar girdles	-	Reflective vest	- Safety boots
-	Protective glasses	-	Safety gloves	- Safety helmet
-	Safety gloves	-	Thermal gloves	- Reflective vest
-	Perimeter dimensioning	-	Lifeline	- Dorsal-lumbar girdle
		-	Apron	- Protective glasses
		-	Knee pads	- Safety gloves
		-	Lower zone delimitation	- Thermal gloves
		-	Risk area signage	- Lifeline
04. Sewerage system		**08. Installations**		- Apron
-	Placement of railings on the edge of excavation	-	Placement of nets in façade openings	- Dust mask
-	Non-slip safety boots	-	Noise damper	- Masks
-	Helmet	-	Non-slip safety boots	- Knee pads
-	Dorsal-lumbar girdle	-	Helmet	

Table A1. *Cont.*

Prevention Measures per Chapter		Prevention Measures per Type
- Protective glasses	- Protective glasses	
- Safety gloves	- Safety gloves	
- Dust mask	- Dust mask	
- Excavation bounding	- Knee pads	
- Perimeter dimensioning of utility access hole	- Delimitation of the work area	
05. Structures	**09. Insulation**	**Signalling and delimitation of spaces**
- Placement of rebar protection mushroom caps	- Placement of nets in façade openings	- Excavation bounding
- Railing on forged formwork	- Safety boots	- Perimeter dimensioning of utility access hole
- Railing on sloping slab formwork	- Helmet	- Dimensioning of work area in slab
- Railing on slab	- Reflective vest	- Lower zone delimitation
- Railing on inclined slab	- Protective glasses	- Perimeter dimensioning of the work area
- Horizontal forged hollow railings	- Safety gloves	- Delimitation of passage zones
- Under-forged nets	- Masks	- Risk area signage
- Safety harness	- Knee pads	
- Non-slip safety boots	- Zone bounding	
- Wellies	**10. Coatings**	
- Wellies and safety boots	- Free-edge guardrail	
- Helmet	- Nets in façade openings	
- Safety helmet	- Non-slip safety boots	
- Reflective vest	- Safety boots	
- Dorsal-lumbar girdle	- Helmet	
- Protective glasses	- Reflective vest	
- Safety gloves	- Dorsal-lumbar girdle	
- Lifeline	- Protective glasses	
- Work area delimitation	- Safety gloves	
- Dimensioning of work area in slab	- Masks	
- Perimeter dimensioning	- Knee pads	
- Delimitation of passage zones	- Zone bounding	
	- Lower zone delimitation	

Table A2. Example calculation of the safety costs of the work unit 02PMM00012.

Work Units		Budget		
Procedure		**Quantity (Unit)**	**Unit Cost (EUR/Unit)**	**Cost (EUR)**
Chapter 02, Earthworks Excavation, in shafts, with mechanical means up to 4 m and loading by truck 02PMM00012	Digging in wells and loading by truck			
PrOm02PMM001	Backhoe excavation			
Situation corrected Technical factor Machines Auxiliary means Installations Collective protections	Backhoe loader			0.00
Personal protections	Safety helmet	1.00	1.69	1.69
	Reflective vest	1.00	2.77	2.77
	Non-slip safety boots	1.00	27.79	27.79
Signage and delimitation of spaces	Perimeter shoulder	50.00	1.75	87.50
	Delimit passage areas	20.00	1.75	35.00
Organizational factor	Cleaning of the pits			0.00
	5 min breaks every 30 min			0.00
Environmental factor				
prAl02PMM001	Profiling of bottoms and sides			
Situation corrected Technical factor Machines Auxiliary means Installations Collective protections	Ladder			0.00
Personal protections	Safety helmet	1.00	1.69	1.69
	Reflective vest	1.00	2.77	2.77
	Non-slip and safety boots	1.00	27.79	27.79
	Safety gloves	1.00	4.15	4.15
	Lumbar girdle	1.00	11.99	11.99
Signage and delimitation of spaces	Delimit passage areas			0.00
	Perimeter shoulder			0.00
Organizational factor	Cleaning of the pits			0.00
	5 min breaks every 30 min			0.00
Environmental factor				
Total cost of earthmoving prevention measures		Total cost corrected situation		203.14

Table A3. Calculation of risk reduction per procedure: (Al (mason), Am (insulation fixer), At (tiler), El (electrician), En (formwork), Es (plaster board placer), Fe (rebar worker), Fo (plumber), Ho (concrete mixer), Im (water-proofer), Om (machine operator), So (tiler), and Ye (plasterer). Information per work unit, chapter, and for the total project.

CHAPTER			**Ip**				**% Risk Reduction**			
Unit	**ACCD Unit Code**	**Code of Procedures**	**Initial Risk**		**Final Risk**		**By Procedures**	**By Work Unit**	**By Chapter**	**Total**
02 Earthworks										
Digging foundation pads	02PMM00012	prOm02PMM001	4	15	1	5	75%	67%	67%	65%
		prAl02PMM001	11		4		64%			

Table A3. *Cont.*

CHAPTER	ACCD Unit Code	Code of Procedures	Ip				% Risk Reduction			
Unit			Initial Risk		Final Risk		By Procedures	By Work Unit	By Chapter	Total
03 Foundation										
Concrete slab	03ACC00010	prFe03ACC001	23		9		61%	61%	61%	65%
	03HAZ00002	prHo03HAZ001	17		6		65%	65%		
Contour beams	05HAC00010	prFe05HAC002	26		10		62%	62%		
	03ERM00001	prEn03ERM001	14		7		50%	50%		
	05HHJ00003	prHo05HHJ002	17		8		53%	53%		
04 Sewer system										
Buried sewer system	04EAS00002	prAl04EAS001	11	41	8	26	27%	37%	37%	
		prAl04EAS002	19		10		47%			
		prAl04EAS003	11		8		27%			
	04EAP90002	prAl04EAP001	13	40	8	23	38%	43%		
		prAl04EAP002	17		7		59%			
		prAl04EAP003	10		8		20%			
	04ECP90007	prAl04ECP001	14	46	5	17	64%	63%		
		prAl04ECP002	18		7		61%			
		prAl04ECP003	14		5		64%			
05 Structure										
Self-resilient slab	05FUA00005	prAl05FUA002	18	87	3	17	83%	80%	75%	
		prEn05FUA002	25		6		76%			
		prFe05FUA003	24		4		83%			
		prHo05FUA003	20		4		80%			
Pillars	05HAC00015	prFe05HAC003	18		6		67%	67%		
	05HET00001	prEn05HET001	23		6		74%	74%		
	05HHP00103	prHo05HHP001	16		4		75%	75%		
	05HED00051	prEn05HED001	23		6		74%	74%		
Waffle slab	05FBB00007	prEn05FBB002	26	62	7	18	73%	71%		
		prFe05FBB002	20		6		70%			
		prHo05FBB002	16		5		69%			
Inclined slab	05HEM00101	prEn05HEM002	26		7		73%	73%		
	05HAC00015	prFe05HAC002	20		6		70%	70%		
	05HHL00103	prHo05HHL002	16		4		75%	75%		
	05HED00001	prEn05HED002	19		5		74%	74%		
06 Masonry work										
Enclosure	06LPM00001	prAl06LPM001	15		5		67%	67%	69%	
	06LPM00004	prAl06LPM002	13		5		62%	62%		
Partitions	06DSS00001	prAl06DSS001	17		4		76%	76%		

Table A3. *Cont.*

CHAPTER	ACCD Unit Code	Code of Procedures	Ip				% Risk Reduction			
Unit			Initial Risk		Final Risk		By Procedures	By Work Unit	By Chapter	Total
07 Roof										
Flat roof	06LPM00001	prAl06LPM001	17		6		65%	65%	69%	65%
	07HNF00021	prAl07HNF001	10	65	4	11	60%	68%		
		prIm07HNF002	17		4		76%			
		prAl07HNF003	10		3		70%			
		prAl07HNF004	10		0		70%			
		prAl07HNF005	10		0		70%			
		prAl07HNF006	8		0		50%			
	10CEE00001	prAl10CEE001	11		6		45%	45%		
	07HNE00001	prAl07HNE001	18	44	3	10	83%	77%		
		prIm07HNE002	16		4		75%			
		prAl07HNE003	10		3		70%			
08 Installations										
Electricity Installation	08ECC00001	prAl08ECC001	16	27	8	14	79%	48%	66%	
		prEl08ECC001	11		6		45%			
	08EDD00004	prAl08EDD001	17	28	8	14	79%	50%		
		prEl08EDD001	11		6		45%			
	08ELL00001	prAl08ELL001	15	25	7	12	79%	52%		
		prEl08ELL001	10		5		50%			
	08ETT00003	prAl08ETT001	15	25	0	0	79%	52%		
		prEl08ETT001	10		0		50%			
	8EWW00040	prAl08EWW001	12	18	5	7	79%	61%		
		prEl08EWW001	6		2		67%			
	08EID00007	prEl08EID001	5		2		60%	60%		
	08EIM00102	prEl08EIM001	5		2		60%	60%		
Water Installation	08FAC00204	prFo08FAC001	11		3		73%	73%		
	08FAC00410	prFo08FAC002	11	30	3	9	73%	70%		
		prAl08FAC001	19		6		68%			
	08FDP00022	prFo08FDP001	12	31	3	8	75%	74%		
		prAl08FDP001	19		5		74%			
	08FDP00050	prFo08FDP002	12	31	3	8	75%	74%		
		prAl08FDP002	19		5		74%			
	08FDP00091	prFo08FDP003	12	31	3	8	75%	74%		
		prAl08FDP003	19		5		74%			
	08FFP90300	prFo08FFP001	13	33	5	11	62%	67%		
		prAl08FFP001	20		6		70%			

Table A3. *Cont.*

CHAPTER	ACCD Unit Code	Code of Procedures	Ip				% Risk Reduction			
Unit			Initial Risk		Final Risk		By Procedures	By Work Unit	By Chapter	Total
Water Installation	08FFP90320	prFo08FFP002	13	33	5	11	62%	67%	66%	65%
		prAl08FFP002	20		6		70%			
	08FFP90830	prFo08FFP003	15	35	5	11	67%	69%		
		prAl08FFP003	20		6		70%			
	08FGN00103	prFo08FGN001	12		3		75%	75%		
	08FSW00101	prFo08FSW001	11	27	3	6	73%	78%		
		prAl08FSW001	16		3		81%			
	08FTC00651	prFo08FTC001	13	32	5	11	62%	66%		
		prAl08FTC001	19		6		68%			
	08FVL00003	prFo08FVL001	12		3		75%	75%		
	08FVW00002	prFo08FVW001	12		3		75%	75%		
09 Insulation										
Insulation	09TPP90220	prAl09TPP001	32	50	14	23	56%	54%	54%	
		prAm09TPP002	18		9		50%			
Finishes										
Trimming and plastering walls	10CGG00006	prYe10CGG002	15		9		40%	40%	58%	
Tiling	10AAE00023	prAt10AAE002	29		14		52%	52%		
Ceramic flooring	10SCS00003	prSo10SCS001	19		7		63%	63%		
Terrazzo flooring	10STS00001	prSo10STS001	19		7		63%	63%		
Plaster ceiling	10TET00005	prEs10TET001	18		8		56%	56%		
Trimming and plastering walls	10CGG00005	prYe10CGG001	15		9		40%	40%		
Tiles of staircase	10PNP00001	prSo10PNP001	16		5		69%	69%		
	10PNZ00001	prSo10PNZ001	16		5		69%	69%		
Monolayer	10CWW00006	prAl10CWW001	15		5		67%	67%		
	10CWW00012	prAl10CWW002	15		5		67%	67%		
	10CWW00021	prAl10CWW003	15		5		67%	67%		

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