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The Accident Rate in the Construction Sector: A Work Proposal for Its Reduction through the Standardization of Safe Work Processes

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Abstract: The statistics on work-related accidents published by the responsible organizations reveal that the average rate of work accidents within the construction sector is more than double that in other industrial sectors. This serious problem has been analyzed by numerous international organizations and institutes dedicated to occupational safety, health and welfare. Therefore, in this article, some results of a research project that aims to reduce workplace accidents through the standardization of safe work processes and procedures in construction sites are summarized. The proposed methodology consisted of the analysis of national and international bibliographies to analyze the different annual variations in the accident rate, allowing a common pattern to be located, as well as its association with the work processes carried out in construction projects to standardize each of the processes which are present in the execution and life phases of the building. It is possible to conclude that the accident rates can be reduced and/or eliminated with the application of each of the processes thanks to the obtained results.

Keywords: construction; prevention; risk; safety; processes; procedure

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1. Introduction

The construction sector is immersed in a circular flow where increases and decreases in the rate of work-related accidents occur, specifically, in those data related to work accidents and fatal accidents.

Around three million workers die each year as a result of work-related accidents [1]. Around 2.6 million of these deaths are due to occupational diseases, while work-related accidents account for 333,000 deaths, according to the International Labor Organization (ILO) analysis.

Another report under analysis, published by the European Agency for Safety and Health at Work, Occupational Safety and Health in Europe: state and trends 2023 [2], provides worrying data on construction and accidents.

Table 1 shows the data collected by the ILO comparing more than 60 countries participating in the sample. The data collected are on non-fatal occupational injuries, occupational fatalities, and inspectors.

The incorporated data from the analyses carried out by the ILO show that countries known as members of the G2, due to their appearance as economic powers, hold the top positions for rates of accidents, and include some of the countries belonging to the EU [3].

Most reports from more and more Spanish organizations show that the percentages and results related to work-related accidents are worrying. In February 2023, the Confederal Secretary of Occupational Health and Environmental Sustainability of the Trade Union Confederation of Workers' Commissions published its report titled "Analysis of the statistics of occupational accidents and diseases in Spain in 2022" [4], where they describe a

10% approximate increase in work-related accidents with sick leave and a 17% increase in mortal accidents.

Table 1. Occupational safety and health indicators. International Labour Organization. ILOSTAT Last update: 11 January 2024.

Country	Non-Fatal Occupational Injuries per 100,000 Workers	Occupational Fatalities per 100,000 Workers	Inspectors per 10,000 Workers
Costa Rica	9421	9.7	0.6
Argentina	3587	3.3	0.3
Chile	3142	3.1	0.8
France	3043	2.6	0.8
Denmark	2814	1.4	-
Pakistan	2691	-	-
Luxembourg	2690	1.8	2.8
Uruguay	2654	3.7	0.6
Mexico	2529	7.7	0.1
Portugal	2499	1.9	0.9
Türkiye	2459	6.3	0.3
Spain	2347	1.9	1.1
Belgium	2314	0.0	0.6
Switzerland	2006	0.8	1.3
Macau, China	1891	6.9	2.7
Finland	1637	0.7	1.3
Slovenia	1599	1.5	0.9
Austria	1513	2.9	0.7
Germany	1496	0.7	1.4
Canada	1464	5.7	0.1
Brazil	1374	-	-
Italy	1209	2.7	-
New Zealand	1200	2.3	0.3
Hong Kong, China	1188	6.8	-
Netherlands	1072	0.3	-
Israel	1062	1.1	0.5
Belize	910	5.2	1.4
United States	900	5.3	0.1
Australia	899	1.6	-
Malta	863	3.3	0.2
Czechia	779	1.9	1.0
Thailand	762	5.3	0.2
United Kingdom	692	0.8	0.3
Sweden	689	0.8	0.5
Ireland	688	1.4	0.3
Egypt	670	10.7	-

Table 1. *Cont.*

Country	Non-Fatal Occupational Injuries per 100,000 Workers	Occupational Fatalities per 100,000 Workers	Inspectors per 10,000 Workers
Singapore	613	1.3	1.1
Croatia	605	2.2	1.1
Estonia	546	2.2	0.7
Poland	473	1.5	0.9
Hungary	452	1.5	0.6
Japan	266	1.5	0.5
Ukraine	166	7.6	0.8
Greece	117	0.6	-
Russian Federation	96	5.0	-
Palestinian	74	1.0	0.9
Romania	71	1.8	1.9
Norway	48	1.1	1.2
Qatar	40	3.0	1.3
Guatemala	28	0.1	0.2
Colombia	4	0.0	0.4

Present-day work-related accidents are accompanied with headlines, news and digital documents [5–9]. Due to these headlines, and thanks to the accident rate data published regularly by the National Institute for Safety and Health at Work, the current working conditions in Spain are shown.

The data collected in Table 2 show a comparison of the accident rates in different sectors during the annual periods between 2021 and 2023, shown in the 2021, 2022, and 2023 columns.

Table 2. Comparison of sectoral incidence rates of work-related accidents during workday (years 2021–2023) [10].

Sectoral	Rate 2023	Rate 2022	Rate 2021
Agricultural	4199.80	4204.80	4318.70
Industry	4633.80	4519.30	4426.00
Construction	6298.60	6329.60	6316.70
Services	2160.10	2350.60	2166.70
Total	2812.40	2950.70	2810.50

Furthermore, and as will be shown in the methodology, the data presented do not improve with the passage of years, but a progressive increase is observed without current perspectives or predictions of a notable improvement.

In Table 2, the sectoral incidence rates of work-related accidents of workers in the construction sector during 2021–2022 are compared, where they describe an increase in variation of 0.2 points. In 2022–2023, the values suffered a further reduction, but far from that reflected in the numbers presented in 2020–2021 due to the construction-related total rate of paralysation after the Royal Decree 463/2020 came into force in 14 March, when a state of alertness was declared to manage the sanitary crisis caused by COVID-19 [11]. This was a scenario that, as time went by, confirmed that this reduction happened because of the total rate of paralysation, not because of an improvement. Figure 1 shows the graphical evolution of the incidence of work-related accidents in the construction sector.

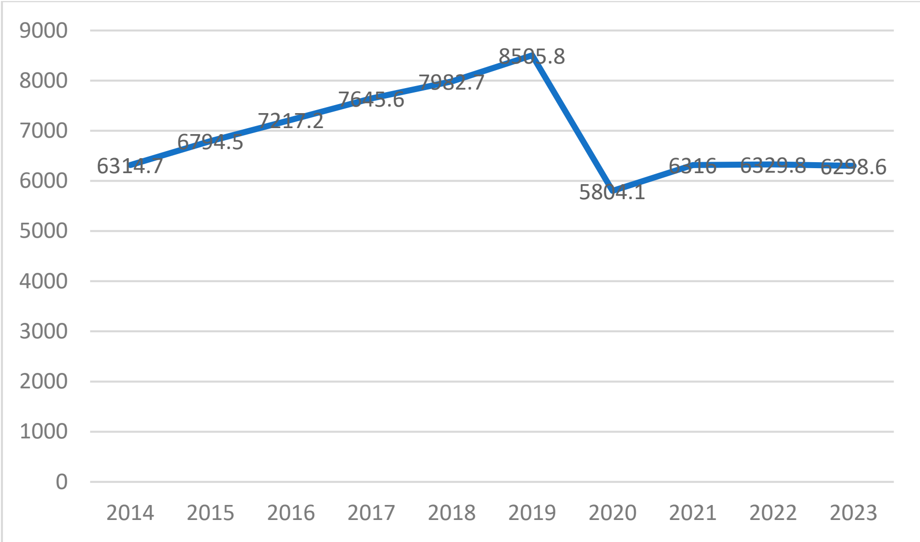

Figure 1. Incidence rates of work-related accidents with sick leave in the construction sector. Evolution from 2014 to 2023 [12–19].

Outside Spanish territory, the numbers tend to differ, since between 2010 and 2019 the average data in the European Union showed a decreasing trend in fatal and non-fatal work-related accidents. However, as mentioned, in Spain, the data did not improve, but rather the rate of fatal accidents increased significantly. In 2010, the national data coincided with the European Union (EU) average, this level being 2.87 fatal work-related accidents per 100,000 workers, while in 2019, both indices were very far apart: Spain was positioned at 3.27 compared to the European Union, at 2.17 [20].

In order to find a possible reason for the current situation, it can be seen that existing regulations for prevention have not had any modifications to achieve a reduction in accidents; moreover, measures are not even shown that are related to technical factors or human factors in the recent publication by the Spanish Strategy for Occupational Health and Safety 2023–2027 [21], or the Sustainable Development Goals (SDGs) 03, good health and well-being; 08, decent work and economic growth; and 09, industry, innovation and infrastructure [22]. When talking about costs and economic resources set aside for vigilance and the control of security and health, these are minimal, not setting these resources to the level they belong.

Considering incorrect execution, it is possible to work on different proposals to deal with the methodology to be studied [23]. The precarious environment [24] is not unexpected by any professional in the sector [25]. This scenario should be a relevant example that initiates the implementation of different preventive measures which encourage the reduction in the high work-related accident rates.

Scarce training evinces a lack of professionality [26]. Knowledge of guidelines linked to the functioning of construction sites and the measures and rules in safety and health are essential requirements. Therefore, improvement actions must be taken to elaborate guidelines, processes, and procedures for safe work in construction units, providing workers with detailed information about tasks to be performed, visibility, how to avoid being exposed to risks, or preventive measures that should be implemented to guarantee a safe work environment where safety prevails, and not production as usual.

1.1. Risk Evaluation Methods

To ensure improvement actions, and in relation to Spanish regulations, there are different risk assessment methods within the framework of this study. Many assessment methods can be applied, so adaptation to the corresponding needs is required depending on the evaluation field for an appropriate choice. Below are some of the most common and widely used methods in risk assessment in three preventive areas: safety, ergonomics, and psychosociology [27].

1.1.1. Safety

- The National Institute of Safety and Hygiene at Work's method: this is based on a work activity classification where variables are analyzed, identifying dangers, considering risks, and finally appreciating whether they are tolerable or not [28].
- NTP-330, of the National Institute of Safety and Hygiene at Work method: this method tries to ease the task of evaluating risks by means of filling check surveys [29].

1.1.2. Ergonomics

- The Rapid Entire Body Assessment (REBA) method: this method evaluates individual postures and not group or posture sequences [30].
- The Ovako Working Analysis System (OWAS) method: this method allows for the assessment of physical charge derived from postures assessed during work time [31].
- The Rapid Upper Limb Assessment (RULA) method: in this method, postures will be selected according to their postural charge (by means of their duration, frequency or deviation from neutral posture) [32].

1.1.3. Psychosociology

- The evaluation of psychosocial factors of the National Institute of Safety and Hygiene at Work (FPSICO) method: the F-Psico method offers information about the following risk factors: work time, autonomy, work charge, psychological demands, variety/content, participation/supervision, interest/compensation, roll performance, relationships, and social support [33].
- The COPSOQ method: this method has been designed on the basis of epidemiologic methodology and the use of standardized surveys, the participation of preventing agents in companies, and result triangulation [34].

1.2. Standardization Process

Standardization is understood as the unification of the processes and procedures to which the different tasks or activities of a productive sector can be subjected with the purpose of creating a model or manual which is reproducible at work and where the established quality and safety parameters are met.

With the unification of processes, a notable reduction in risks is achieved with the creation of protocols without resulting in high levels of probability of failure. The compliance with standards is improved and a greater efficiency is achieved in the production chain.

If the standardization processes are applied to the construction sector, through a detailed analysis of the work to be carried out, accompanied by a risk assessment and subsequent application of preventive measures, the reduction in the risk factor to which workers are subjected in the construction sector will be achieved, as will be seen in this article [35–38].

1.3. General and Specific Objectives

Once the content of this article is introduced, it can be determined that this study will have as its main goal a focus on risk evaluation linked to work procedures for each existing work unit, besides integrating preventive measures for, as mentioned previously, reaching a reduction in or suppression of work-related accident rates in the construction sector. For the reader's understanding of the achievement of the general aim, the development of a work unit will be presented as an initial example to standardize processes and reach safe work standards, provided that selected criteria are determined.

On the other side, the specific criteria are the following: 1—Suggesting a design for the development of writing the work procedure and providing guidelines for the codification of its subsequent integration, in case they do not in any database linked to construction costs. 2—Making visible the criteria and guidelines for the standardization of the work procedures of any work unit, and the possibility of incorporating work risk prevention plans.

Figure 2 shows a graphic summary with answers to the indirect questions posed due to the increase in occupational accidents as a result of the lack of safe work patterns in the construction sector or the lack of their documentation.

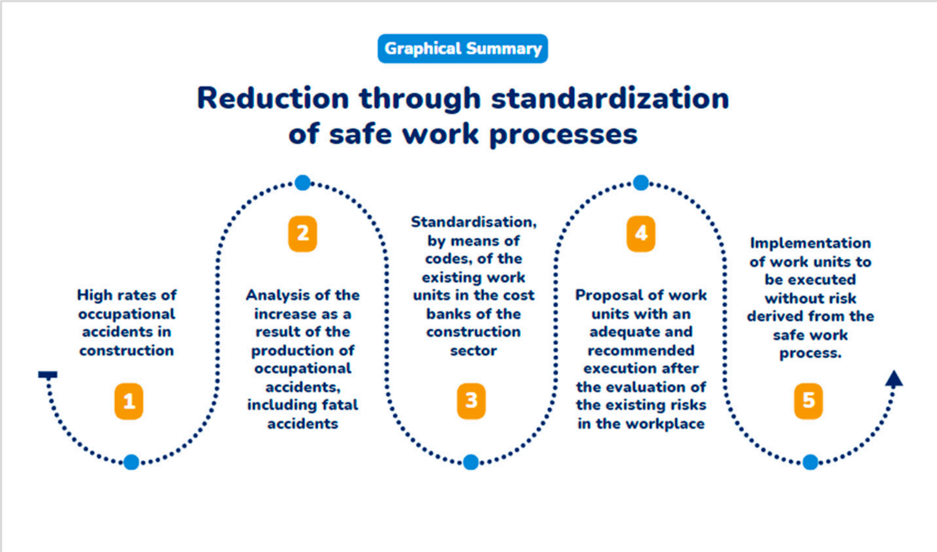

Figure 2. Graphic summary of the ideas that promote research on the reduction in accidents through standardization.

2. Materials and Methods

The materials available to develop the work methodology detailed in this article can be grouped into five different phases based on their state of evolution. Figure 3 details how the methodology is grouped into five major phases where the different phases of action and/or execution of the structure are encompassed.

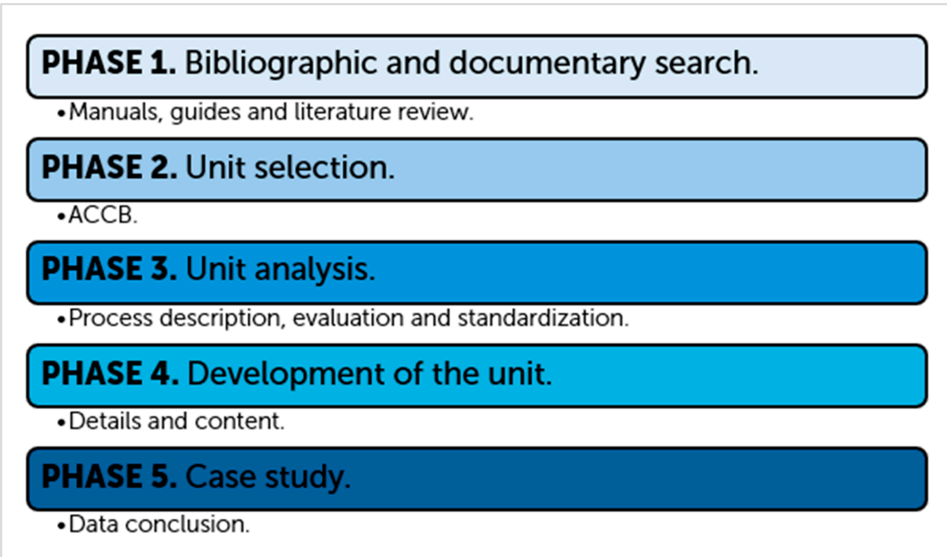

Figure 3. Phases of the methodology.

PHASE 1 begins with the compilation of a bibliographic search, with the data and content included in scientific and informative documents. The research analyzes different scientific contributions through the publication of recent articles, which deal with the contributions that other researchers have located and analyzed in the field of action [39–45].

After the initial statistical data are presented in the introduction and addressed in the results, the preventive factors with the greatest impact on work-related accidents in the construction sector are determined [Table 2]. From here and with the selection of the cost base to be used, it is possible to work on the details of the work methodology in a practical and expository way, configuring PHASE 2.

The work methodology is divided into two differentiated actions in the action system. On the one hand, fieldwork will be carried out and actions to be carried out in the work center will be analyzed, with the obtention of photographs and videos as well as verbal information provided by the workers who are in the work area. On the other hand, office work, where each piece of data and processes collected from site visits will be presented and analyzed.

Once the unit of work which will be subjected to the analysis has been decided, the next stage begins, PHASE 3, in which a search is carried out for the existing regulations to consult regarding the information [Table 3] and guidelines established around its execution, the existence of processes, constructive recommendations, etc. Afterwards, the trades [46] that intervene during the execution are defined, which is a relevant part of the development of the unit since it will be important data for the subsequent codification of and approach to the safe work procedure.

Table 3. Glossary of current international regulations on occupational risk prevention compared to European regulations.

Country	Regulation and Description
European Union	Directive 89/391/EEC. Implementation of measures to promote the improvement of the Safety and Health of workers at work.
Spain	Eq. Law 31/1995 on the Prevention of Occupational Risks
France	Eq. Labour Code, Part IV
Portugal	Eq. Law No. 102/2009, Legal Regime for the Promotion of Safety and Health at Work.
Germany	Eq. Act on the Implementation of the EC Framework Directive on Occupational Safety and Health
United Kingdom	Eq. The Health and Safety at Work Act, 1974 (HSW)
Italy	Eq. Legislative Decree No. 81 of 9 April 2008
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European union	Directive 89/655/eec. Minimum safety and health requirements for the use of work equipment by workers at work.
Spain	Eq. Royal Decree 1215/1997
France	Eq. Labour Code, Part IV
Portugal	Eq. Decree-Law 331/93
Germany	Eq. Regulation on Safety and Security Health protection when using work equipment at work
United Kingdom	Eq. Provision and Use of Work Equipment Regulations, 1998
Italy	Eq. Legislative Decree No. 81 of 9 April 2008
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European Union	Directive 2006/42/EC. Laws of the Member States relating to machinery.
Spain	Eq. Royal Decree 1644/2008
France	Eq. Decree No. 2008-1156 of 7 November 2008
Portugal	Eq. Decree-Law 103/2008
Germany	Not transposed
United Kingdom	Eq. Supply of Machinery (Safety) Regulations 1992
Italy	Eq. Legislative Decree No. 17 of 27 January 2010

Table 3. *Cont.*

Country	Regulation and Description
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European Union	Directive 89/654/EEC. Minimum Safety and Health requirements at the workplace.
Spain	Eq. Royal Decree 486/1997
France	Eq. LAW No. 91-663 of 13 July 1991
Portugal	Eq. Decreee-Law 347/93
Germany	Eq. Workplace Ordinance
United Kingdom	Eq. Workplace (Health, Safety and Welfare) Regulations 1992
Italy	Eq. Legislative Decree No. 81 of 9 April 2008
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European Union	Directive 90/269/CEE. Minimum Safety and Health requirements for the manual handling of Loads involving risks, in particular back hazards, to workers
Spain	Eq. Royal Decree 487/1997
France	Eq. Decree No. 92-958 of 3 September 1992
Portugal	Eq. Decree-Law 330/93
Germany	Eq. Regulation on Safety and Security Health protection in manual Load handling
United Kingdom	Eq. Manual Handling Operations Regulations, 1992 (MHOR)
Italy	Eq. Legislative Decree No. 81 of 9 April 2008
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European Union	Directive 89/656/EEC. Minimum Safety and Health requirements for the use of personal protective equipment by workers at work.
Spain	Eq. Royal Decree 773/1997
France	Eq. LAW No. 91-1414 of 31 December 1991 amending the Labour Code and the public health.
Portugal	Eq. Decree-Law 348/93
Germany	Eq. Regulation on safety and security Health protection during use personal protective equipment at work
United Kingdom	Eq. Personal Protective Equipment at Work Regulations, 1992
Italy	Eq. Legislative Decree No. 81 of 9 April 2008
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European Union	Directive 2002/44/EC. Minimum Safety and Health requirements relating to the exposure of workers to the risks arising from physical agents (Vibrations).
Spain	Eq. Royal Decree 1311/2005
France	Eq. Decree No. 2005-746 of 4 July 2005
Portugal	Eq. Decree-Law 46/2006
Germany	Not transposed
United Kingdom	Eq. Control of Vibration at Work Regulations, 2005
Italy	Eq. Legislative Decree No. 187 of 19 August 2005
United States	Eq. OHS Act—Health and Safety Law. Standards 29
European Union	Directive 2003/10/EC. Minimum Safety and Health requirements relating to the exposure of workers to the risks arising from physical agents (Noise).
Spain	Eq. Royal Decree 286/2006
France	Eq. Decree No. 2006-892 of 19 July 2006
Portugal	Eq. Decree-Law 182/2006
Germany	Eq. Accident prevention regulations "Occupational Health Care" (VBG 100) "Accident Prevention Regulation"
United Kingdom	Eq. The Control of Noise at Work Regulations, 2005
Italy	Eq. Legislative Decree No. 195 of 10 April 2006
United States	Eq. OHS Act—Health and Safety Law. Standards 29

Having the procedure fully set up, as well as correctly codified, PHASE 4 will be described, bearing in mind what the starting point is when initiating work, the description of the tasks involved, procedures, and final situation. Once redacting is finished, a series of resources, equipment usage, materials, and machinery will be assigned for its execution.

Whether or not it is intended to develop an analysis and posterior identification of each of the present risks as the main objective of the work, all of this has to be supported in a task list, where intervention points will be established to allow for the verification of existing risks in each of the tasks generated in a fast and visual way.

Afterwards, risk evaluations will continue, which are important in the field of prevention, as they are in security, ergonomics, and psychosociology, and as they will be the key factors to establish the method. Once the evaluation is finished, preventive actions will be provided to set safe work guidelines, conditioned to the risk levels resulting from the evaluation and with the consequent implementation and launch of the measures in the execution of the work unit. Thus, greater safety can be guaranteed for all of those involved.

To conclude, PHASE 5, in which the modification of the original design will be detailed, is established prior to the implementation and development of the unit, indicating from the first moment the measures that are implemented in the initial execution situation. A risk reassessment will be carried out with the same methods and tools to verify the effectiveness of the preventive measures implemented and the adhesion of the graphic and statistical elements, in which the quantitative data are visible.

In Figure 4, it is possible to see the breakdown of the five work phases which make up the work methodology. Point number 1 of the design corresponds to phase 1, point number 2 shapes phase 2. Points 3 and 4 of the design configure phase 3. Phase 4, the most extensive phase of the design, covers points 5 to 9 and, finally, phase 5 corresponds to point 10 of the design.

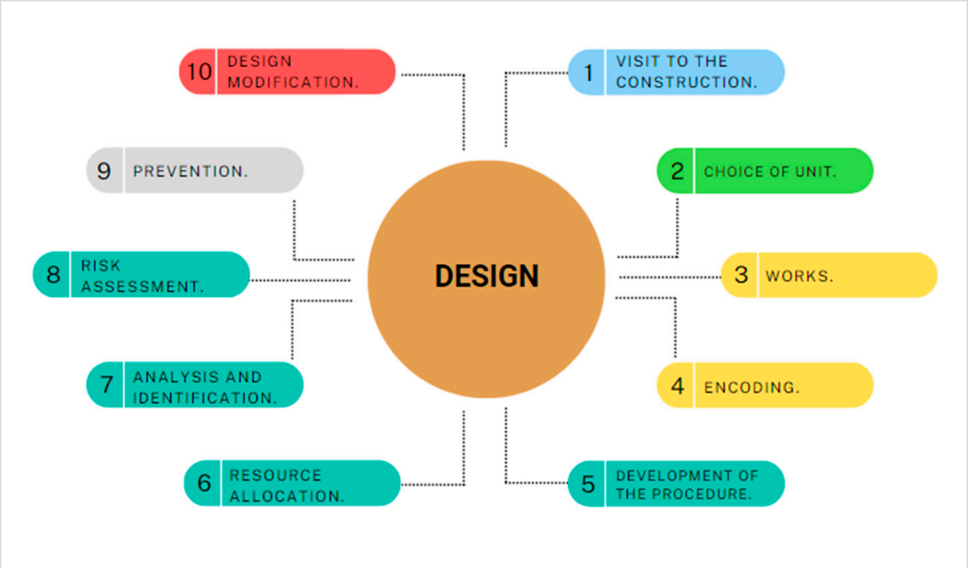

Figure 4. Developed methodology design.

3. Results

Derived from the extensive bibliographic research, a few documents that deal with the investigated topic "Analysis and treatment of building work procedures. Plastering" will be discussed. Occasionally, the work content will be paraphrased, as well as quotes and technical documentation dated after its documentation [47–54].

This work is the starting point in the implementation of the work system, which includes a broader framework or vision of the different existing work units as well as the incorporation of psychosocial analysis in the evaluation of risks present on a day-to-day basis of the people in charge of executing different work processes.

In addition to these academic works, all of them from Spanish universities due to the failure to study and address this line of study outside Spain, a normative search has been carried out on preventive matters, of international, common or specific applications, so that the possible common patterns in the different existing regulations were located and analyzed, and the facilitation of the work could be achieved. Table 3 shows the information obtained.

With modifications and updates of the research, experts in the field have offered various models focused on business organization [55], regardless of the productive sector [56] with which it was related, in which the common point was the need for a continuous improvement in quality [57].

Despite the aforementioned points, the topic under investigation starts with an initial approach, though not as detailed as the current one, through the publication "Management model for the comprehensive prevention of occupational risks in construction sites" [35], where a specific and objective model is achieved that shapes the prevention plan for companies included in the construction sector.

The plan includes the theoretical and practical concepts and patterns to be considered for its proper drafting. The introduction of the concept of a "procedure" together with "standardization" allows the doctoral work to encompass the various specific objectives that future researchers must achieve as a final point for the proper attainment of the results.

To lay the foundations for the documentation and information, two tables can be presented including, on one hand, in Table 4, the descriptive variables of fatal work accidents, and on the other hand, in Table 5, the main causes of the accidents, both in the construction sector.

Table 4. Prominent categories of descriptive variables in fatal occupational accidents. Construction sector. Analysis of work-related mortality in Spain, 2020–2022.

Variable Descriptive	TAM Construction	TAM Totals
Type of place		
Works, constructions	63.70%	25.20%
Industrial areas	11.30%	36.00%
Type of work		
Earthworks	54.80%	22.00%
Maintenance	33.30%	31.60%
Physical activity		
Movement	33.30%	23.40%
Object handling	18.50%	14.30%
Be present	14.30%	14.00%
Hand tools	13.70%	11.70%
Deviation		
Fall of people	35.70%	19.90%
Break, burst	33.30%	26.70%
Loss of control	12.50%	24.30%
Contact form		
Hitting an object	51.20%	28.30%
Get caught	18.50%	33.60%
Crashing into an object	14.90%	20.80%

Through the Section 1, the existing methods and/or models that are most used were defined based on the specific research need, and consequently on the process and work unit, as well as on the approach to continuous improvement needs in occupational safety and health in the workplace environment. It can be determined that, in the case of the safety risks evaluated, the method to be used will be the NTP-330 of the National Institute of Safety and Hygiene at Work method due to its agile handling and precision in data from the verification and completion of the checklist questionnaire.

Table 5. Main causes of fatal occupational accidents in the construction sector. Construction sector. Analysis of work-related mortality in Spain, 2020–2022. INSST.

Causes	% Causes	% Total Causes	% TAM
Absence/deficiency of collective protection	7.10%	3.80%	27.40%
Inadequate working method	5.40%	4.70%	20.80%
Absence of surveillance	3.80%	2.30%	14.90%
Non-use of personal protective equipment	3.40%	2.20%	13.10%
Lack of presence of the preventive appeal	3.20%	1.40%	12.50%
Staying in a dangerous area	3.10%	4.70%	11.90%
Lack of structural safety	2.90%	1.50%	11.30%
Non-existent procedures	2.80%	2.10%	10.70%
Failure to identify risks	2.60%	4.10%	10.10%
No processes to direct the activity	2.60%	1.40%	10.10%
Failure to comply with the Security Plan	2.60%	1.10%	10.10%
No information or training	2.50%	2.50%	9.50%
Proposed preventive measures	2.50%	1.60%	9.50%
No processes to regulate planning	2.50%	1.30%	9.50%
Failure to implement preventive measures	2.30%	2.60%	8.90%
Non-existent working methods	2.20%	2.30%	8.30%
Inadequate training and information	2.00%	2.90%	7.70%
Other causes of behaviour	1.80%	2.60%	7.10%
Failure to provide protective equipment	1.80%	1.60%	7.10%
% selected causes CONSTRUCTION	49.00%	46.40%	

For the assessed ergonomic risks, the Rapid Entire Body Assessment (REBA) method [58] will be used because its evaluation focuses on individual postures [59], providing the option to analyze a specific job responsible for executing the work unit, as well as assessing postures that involve a greater postural load due to factors such as duration or repetition [60].

For the assessed psychosocial risks, the National Institute of Safety and Hygiene at Work (FPSICO) method will be used. This method, through its digital tool, provides simplicity in the responses from those evaluated, as well as ensuring a fully anonymous individual evaluation process that guarantees confidentiality in this evaluation field.

Previously, the dual field–office work system was described. The results that this duality contributes, initially pertaining to field activities, can be verified through site visits. During these visits, images and videos will be collected showing the different functions of the work units, allowing for a comprehensive analysis of the work processes carried out. Whenever possible, references and comments provided by the workforce at the workplace will be considered, whether from the material execution management, foreman, or execution teams. It should be emphasized that access to the site will require the necessary authorizations and permissions to operate inside. Access will be made with mandatory and regulatory protective equipment appropriate to the work environment, such as helmets, safety footwear, etc.

Figure 5 presents a small sample of the standardization process for the task of a specific work unit, considering, for the sample, the unit "Execution of plastering on the facing of a facade", and the level and sublevel task 3.2., "Removal of burrs and protrusions with the help of the trowel".

(**a**)

(**b**)

Figure 5. Work unit: (**a**) location of the work area within the construction site; (**b**) status of the execution area of the work unit.

In Table 6, the different autonomous communities with their own price databases are listed. For the research, the database from Andalucía will be used.

Table 6. List of autonomous communities in Spanish territory with their own cost database for the construction sector.

Autonomous Community	Responsible	Last Updated
Andalusia	R. Govt. of Andalusia	2023
Aragon	-	-
Asturias	FACEA	2023
Castilla la Mancha	-	-
Castilla y León	-	-
Catalonia	ITEC	-
Extremadura	R. Govt. of Extremadura	2023
Galicia	Galician Housing Institute	2012
Balearic Islands	COAAT Mallorca	2022
Canary Islands	CIEC Govt. of Canary	-
Madrid	Community of Madrid	2022
Murcia	Region of Murcia	-
Basque Country	-	-
Valencia	Valencian Institute of Const.	2023

With the collection of data, images, videos (in accordance with the provisions of Organic Law 3/2018, of 5 December, on the Protection of Personal Data and guarantee of digital rights, consent and authorization will be requested from the responsible individuals at the workplace to obtain digital content of the various actions during the execution of the work unit, while the corresponding job is involved) and the information obtained at the workplace, the details provided by the working personnel will be transferred to office work. Each work unit to be studied will be selected one by one. Although the total amount of images and videos will not be shared, they will be fully analyzed for the proper drafting of the work process and procedure, as well as for the detection of each of the possible existing risks. Once the unit is identified, the chosen database, the Andalusian Construction Cost Base (ACCB) [61,62], will be consulted to define the chapter or subchapter to which it belongs.

Thanks to the work "Systematic classification of work procedures" [63], it is agreed, after a review and update, in conjunction with the data published by the Andalusian Construction Cost Base (ACCB) [62], the work codes that will define each one of the work units included in the Andalusian prices.

It is important to emphasize that this will be crucial, as it is the only way, together with the data from the cost base, that will allow us to easily control the classification system which is used. The traditional coding system is maintained, generating a combination of alphanumeric characters so as not to limit the option of creating new codes in case they do not exist or if a code linked to a specific work unit is not available.

Through onsite visits resulting from fieldwork, firsthand information about the various tasks carried out to develop the execution of the work will be retrieved. In a phased manner, maintaining a defined structure, a division of levels will be used. The division will have main levels associated with the main tasks, e.g., level 1, while secondary levels will break down secondary tasks flowing from the main level, e.g., level 1.1, and so on sequentially. Once the list is completed, with each task and subtask compiled using digital content and documentation from existing work processes, a summary of the final situation will be given following the completion of the unit execution. The completion status will be modified once preventive measures to implement have been proposed.

One of the alphanumeric characters that make up the unit code corresponds to resources, and specifically trades. This is why resource allocation takes on special significance, as the standardization process application must continuously consider the assigned resource. The allocation will consist of three generic groups: 1. Labour; 2. machinery, tools, temporary installations, and auxiliary equipment; and 3. location for materials.

Correlated with the tasks to be executed and their corresponding systematic classification of levels and sublevels, risks will be linked to each of these levels as they appear. The tasks and subtasks that make up a set will be identified in blocks, so that the described risks will be present from the beginning to the end of the execution. To simplify the reader's understanding of the work, and continuing with the alphanumeric criterion, the following will be established for each type of risk: the abbreviation "RS" for safety risks, "RE" for ergonomic risks, and "RP" for psychosocial risks. Next to the abbreviation RS, RE, or RP, a number indicating the assigned order of the risk will appear to compute the work reference.

Once the risks are identified, each alphanumeric code belonging to each of the three preventive measures will be recorded, along with a detailed description of the risk during task execution. This creates a glossary of each of the initial exposure risks created, as well as the risks which will need to be evaluated according to the method to be applied.

Tables 7 and 8 show the risk summaries, RS and RE, detected in the work unit used as an example.

Table 7. Summary of safety risks included in the proposed work unit.

Code	Description
RS001	Risk of the worker falling from the scaffold to floor 0.
RS002	Risk of the worker being hit by collision with suspended and/or moving elements.
RS009	Risk of cutting of the worker due to the use of tools and/or materials during execution.

Table 8. Summary of ergonomic risks included in the proposed work unit.

Code	Description
RE005	Risks of MD from repetitive work and posture during clean-up operations.
RE012	Risk of MD due to overexertion during removal of burrs and protrusions.

For the assessment of both safety and ergonomic risks, attention will be paid to the work instructions described by the chosen method in each case. The assessment will only analyze personal injuries, disregarding material damage as this is not relevant to the research. In contrast, for psychosocial risks, a standard assessment will not be conducted; instead, the associated risks collected from previous evaluations will be detailed. The assessment itself is not crucial to the research, as the focus is on proposing psychosocial improvements.

Table 9, depending on the evaluation method chosen for the security risks, shows how this evaluation would look. Table 10 is homologous to Table 9, but it shows the evaluation of ergonomic risks.

Table 9. Security risk assessment prior to preventive measures.

Code	ND	NE	NP	NC	Evaluation	Meaning
RS001	MD	EF	MA-30	M	I3000	Critical situation. Urgent correction
RS002	D	EO	A-12	MG	I 720	Critical situation. Urgent correction
RS009	M	EO	B-4	L	III 40	Improve if possible

Table 10. Ergonomics risk assessment prior to preventive measures.

Code	Group A						Group B						TC	Pac	PF	RL
	T	C	P	TA	F	PA	Br	An	M	TB	Ag	PB				
RE002	3	3	2	6	0	6	1	2	2	2	2	4	7	1	8	HIGH
RE012	1	2	2	2	0	2	2	2	2	3	1	4	3	1	4	MEDIUM

For the assessment of security risks, the values described in Table 9 are collected. Table 9 will take into account the provisions of the NTP-330 of the National Institute of Safety and Hygiene at Work [29]. To this end, and through a series of descriptive tables, the level of risk deficiency (ND), the level of exposure (NE), and the level of probability (NP), which is obtained through (ND)x(NE), as well as the level of consequence (NC), will be calculated, resulting in the level of evaluation or intervention with its meaning. The tables developed in the technical note include numerical values in each section, so following each of them step by step will lead to us obtaining the probability level (NP). Once the probability level has been reached, the steps described will be followed again, where through the alphanumeric code, with the combination of (NP) and (NC), the risk level (NR) will be obtained with its consequent meaning within the intervention level (NI). As an example, in Table 9, it will be seen that the risk coded as RS001 has been evaluated as very deficient (MD) at the level of deficiency (ND) and frequent (EF) at the level of exposure (NE), and that combining both values, a very high probability level (NP) (MA) has been obtained at grade 30. Next, a lethal or catastrophic consequence level (NC), and with the combination of these last two values (NP)x(NC), a risk level (NR) with intervention I in grade 3000 has been evaluated. All this leads to a critical situation that requires urgent correction.

For ergonomic risks, and as described in Table 10, the guidelines described by the Rapid Entire Body Assessment (REBA) method [30] should be taken into account. Starting from two groups, A and B, the affected parts of the body will be represented in the evaluation methodology. For the correct evaluation, and following the steps of the method, through a selection of numerical combinations, the evaluator will select the angular position that the worker must perform for the execution of the task. Group A will be made up of the values associated with the torso (T), neck (C), and legs (P). The combination of group A determines the numerical value (TA), which can be increased depending on the force applied in the execution (F). With all these values, the A score (PA) will be obtained. Group B will be composed of numerical values, following the same guidelines as for group A, associated with arms (Br), forearms (An) and wrists (M). The combination of group B determines the numerical value (TB), which can be increased depending on the grip applied in the execution (Ag). With all these values, the B score (PB) will be obtained. Through a weighting of the values (TA) and (TB) described in the documentation of the method, the total C (TC) will be obtained, whose value may be increased as a result of the activity in the execution (Pac). Once the final score (FP) has been obtained, the level of risk and intervention that the method marks is determined. As an example, in Table 10, it will be seen that the risk coded as RE002 has been evaluated as follows: for group A, (T)+(C)+(P), a value of 6 has been obtained, and since it has no strength in its execution (F), the A score (PA) remains at 6. For group B, (Br)+(An)+(M), a value of 2 has been obtained, and since it has a grip in its execution (Ag) of 2, the score B (PB) is marked as 4. The assessment of (PA) and (PB) gives a total value C (TC) of 7. Since the activity has an increase of +1, the final score (FP) is marked at 8. A final score (PF) of 8 is equivalent to an action level (NA) rated as 3, implying a high risk level (NR) and the need for prompt action.

After assessing each risk, preventive measures to be implemented in the procedure will be detailed. Depending on the risk level resulting from the assessment of each task, the most suitable measure will be decided upon. The adoption of measures aims to reduce or eliminate each risk to ensure the safety of the workers. Similar to the tasks to be executed, a table will be worked on where risks will be listed, some grouped together, based on the measures to be adopted, according to their similarity or coinciding characteristics.

With each of the measures to be adopted for the three types of assessed risks, a new work procedure will be drafted, in which the initial situation will appear completely modified as a result of implementing the preventive measures included. Once the new situation is described, two new branches can be generated: a first branch, where the procedure continues to include tasks already described in the starting situation, thus requiring no modification, and a second branch where, after implementing the measures, the procedure requires the addition or removal of tasks present in the initial situation. This will lead to the description including new levels and/or sublevels of tasks, a new completion status, and, consequently, the development and description of this new situation.

Table 11 shows the preventive measures to be applied once the security and ergonomic risks have been evaluated.

Table 11. Summary of security risks included in the proposed work unit.

Code	Risk and Description of the Preventive Measure
RS001	Risk of the worker falling from the scaffold to floor 0. The scaffolding, at each of its levels, must have a railing to guarantee the worker safety. In addition, the worker must be anchored.
RS002	Risk of the worker being hit by collision with suspended and/or moving elements. The scaffolding, on each of its levels, will have a skirting board in its lower section to avoid possible collisions with the elements. The worker must have all the personal protective equipment that corresponds to their job (safety helmet, safety boots, gloves).
RS009	Risk of cutting of the worker due to the use of tools and/or materials during execution. The worker must use the appropriate personal protective equipment all the time during the execution of the task, including the use of gloves in this case. In the event that the manufacturer indicates any instructions or recommendations in the manual, such instructions or recommendations shall be followed.
RE005	Risks of MD from repetitive work and posture during clean-up operations. To minimize the risk, the worker will be provided with a lumbar girdle as a compression.
RE012	Risk of MD due to overexertion during removal of burrs and protrusions. Training of the worker on the development of safe work, providing guidelines to avoid overexertion, stipulating prior to the start of the day the indications on weight prevention and prolongation of the handling of the maximum loads that can and must be applied during tasks.

As well as working with the initial identification of risks, the same structure of work and design should be continued, with an important nuance: now, risk identification will include the newly implemented preventive measures applied to the new procedures described. Most of the risks identified in the initial procedure will now be eliminated with the adoption of these measures. To represent these risks, they will be marked in a table indicating their disappearance due to the implementation of the measures.

Maintaining the work system, for each of the chosen evaluation methods, a re-evaluation of the risks that persist, even after the implementation of preventive measures, will be conducted in the initial assessment. With this reassessment, it is expected that as a minimum, the risk level will be lower than the initial level due to the implemented measures, which, while not able to eliminate the risk entirely, have succeeded in minimizing harm to the workers.

As a result of the extensive nature of presenting multiple work units and the work design for presenting results, the data obtained after the standardization process is summarized briefly. The analysis includes the trades involved, tasks, subtasks, etc., for the work unit "Mastered and trowelled plaster on walls (on facade)", whose code is 10CEE00003 [23].

The unit is based on the execution of mastered and floated plaster on walls with M5 mortar (1:6) on the entire main façade of a residential building, divided across all the floors. The construction site has a set of buildings distributed around the common areas, in which the task will be replicated.

After completing the design phase of the standardization procedure for this work unit, the following statistical analysis is compiled, as described in the work methodology, on the risks to verify the effectiveness of the measures adopted after their occurrence.

During the execution, and after adopting the different preventive measures, a total of twelve risks have been detected, belonging to the specialty of occupational safety. Three of these twelve risks are computed within risk level I, making up 25%. Four of them are within risk level II, making up 33.40%. One is in risk level III, making up 8.30%. Three of them are within risk level IV, making up 25%, and, finally, one has no anomalies detected, making up 8.30%.

After the adoption of measures, the risks detected have dropped to three. One of them is included in risk level IV, making up 33.34%, and two of them have no anomalies detected, making up 66.66%.

According to these data, it can be concluded that in the face of security risks, it is determined that the adoption of preventive measures has had a positive impact on the implementation of an improvement due to the elimination of 75% of the risks, in addition to the remaining 25% being reduced significantly to level IV and/or without anomalies.

Table 12 shows a complete review of the state before and after the implementation of measures for each of the existing security risks.

Table 12. Comparison of security risk levels before and after the implementation of preventive measures.

Risk Levels	Before the Measures	After the Measures
Level I	3	0
Level II	4	0
Level III	1	0
Level IV	3	1
No anomalies	1	2

Table 13 shows the safety risks still present after the implementation of preventive measures, as described in Table 12.

Table 13. Summar of safety risks included in the proposed work unit after the implementation of preventive measures.

Code	Description
RS001	Risk of the worker falling from the scaffold to floor 0.
RS003	Risk of falling to the same level as the worker as a result of passing through a hole.
RS005	Risk of falling at the same level as the worker due to lack of order and cleanliness.

Dealing with the risks within the specialty of ergonomics, in the execution of the unit prior to adoption, sixteen risks have been collected and classified as follows: three of them are within the medium risk level (4), with 18.75% of the total, three risks are within the medium risk level (5), being 18.75% of the total, two of them are within the medium risk level (6), being 12.75% of the total, one is within the medium risk level (7), being 6.25% of the total, two risks are at the high risk level (8), being 12.50% of the total, and five of them are at the high risk level (9), being 31.25% of the total. No very high (10 or 11) risk levels are detected.

After the adoption of the measures, the detected risks dropped to eight, all of them at the medium risk level (4), making up 100%.

As was the case with the security risk data, the ergonomic risks have achieved the elimination of 50% of the risks after the adoption of the measures. The remaining 50% of the risks have reduced their risk level to a medium risk level (4).

Table 14 shows a complete review of the state before and after the implementation of measures for each of the existing risks in ergonomics.

Table 14. Comparison of ergonomic risk levels before and after the implementation of preventive measures.

Risk Levels	Before the Measures	After the Measures
Medium (4)	3	8
Medium (5)	3	0
Medium (6)	2	0
Medium (7)	1	0
High (8)	2	0
High (9)	5	0
Very High (10)	0	0
Very High (11)	0	0

Table 15 shows the ergonomic risks still present after the implementation of preventive measures, as described in Table 14.

Table 15. Summary of ergonomic risks included in the proposed work unit after the implementation of preventive measures.

Code	Description
RE001	Risk of MD due to repetitive work during loading and unloading of material.
RE002	Risk of MD due to repetitive work during the transport of the material.
RE003	Risk of MD due to repetitive work during the collection of material.
RE004	Risk of MD due to repetitive work during the pouring of bags into injection machines.
RE005	Risks of MD due to repetitive work and posture during clean-up operations.
RE006	Risk of MD due to repetitive work during wetting tasks.
RE007	Risk of MD due to repetitive work during cement spraying operations.
RE008	Risk of MD due to repetitive work during the extension of the cement trowel mixture.

4. Discussion

In order to carry out a correct discussion of the data that has been analyzed, the different stages of the research must be considered, from the broad existing regulatory framework regarding occupational risk prevention, as well as the limited field of informative knowledge on the standardization of processes in the construction sector, up to the stage of paying attention to the results obtained after the execution of each of the standardizations of the different tasks of the work units.

Regarding the regulatory framework, a comparison of a legal catalogue has been presented where each country differs in the rule to apply. Within the European Union, and through the framework guidelines, it is possible to unify the basic concepts for each of the member states. However, if the regulations are extra-community, as is the case in the United States, the scenario changes completely when compiling all articulated guidelines in a single document, OHS Act—Health and Safety Law Standards 29, leaving the total interpretation of the document to the discretion of each technician. This event completely hinders the execution of the standardization of the work units since it does not start from a single scenario and these processes could have different levels or sublevels depending on the country. Objectively, it would be acceptable to propose the use of a common standard, such as what is provided for the election of the cost bank, and to establish a single guideline for its application.

As a consequence of the regulatory diversity, the evaluation methods are in the same situation. Depending on the application and experience of the evaluating technicians, each of the methods will be used more or less frequently, the interpretation or assessment made of the existing risk or risks to which the worker is exposed being totally subjective. As mentioned, the use or not of each of the methods in the development of the research is based on the frequency and ease of application within the construction sector.

The results and values that have been presented in this article confirm the effectiveness and functionality of this line of research, reinforcing this effectiveness in the reduction achieved, where starting from a high number of risks, with their consequent risk levels, this is reduced to around 50–75% of the exposure, giving rise to risks with a very low level or without anomalies, and a reduction of around 40% of the risks that persist, affecting the exposed workers. However, and as with the application of regulations, the criteria that determine what is or what is not within the different preventive fields give rise to different interpretations by technicians. The technical factor, linked to the safety specialty, is subject to a fixed and immovable interpretation since it gives rise to risks derived from the execution of work or the use of equipment; however, human factors, linked to ergonomics and psychosociology, give freedom to each worker who intervenes to abide or not to the decision and work process marked by the technician, in addition to doubting whether they can or should have to address each execution.

It is found that the results and values in different scientific works, referenced in documents [47–54], show a positive trend towards the application of the process. However, and as indicated, the perception of each researcher is totally particular in relation to the level of risk or description of the work methodology. The researchers carry out similar evaluation systems, but the application of standardization is established in different work units such as roofs, installations, air conditioning, carpentry, partitions, and enclosures, contributing more to the reinforcement of the standardization system, but still being very far from the achievement of a clear execution process that allows for the unification of the methodology throughout the construction sector. Once again, the need to generate a single work system that leaves no points unaddressed for the correct description, evaluation and implementation of the work proposal is highlighted.

M.C. González, in his scientific document, manages to achieve a reduction similar to the one proposed, at around 50–70% [47]. In the same way, a similar situation occurs in what is described in the documents of the researchers L. Garnes [49], G. Sánchez [53] or M.J. Riquelme [54]. Therefore, once again, despite the methodological differences, a clear objective is achieved: the reduction in and/or elimination of risk through standardization.

5. Conclusions

Once the methodology for the drafting and analysis of the different work units and the subject of the study, as well as the subsequent standardization, is introduced and developed, the following conclusions are presented, not forgetting that the general objective of the article was to bring together the possible evaluation of work procedures until achieving an integration of preventive measures to achieve a reduction in accidents. The following is achieved.

In each of the units analyzed during the study and document compilation, a series of statistical data has been elaborated and analyzed, showing how once preventive measures are implemented, and consequently, a new work procedure is drafted, there is a noticeable improvement in the present risks, achieving a reduction in the risk level, or even in some cases, their elimination. With the proposed work system, it is clear that the development and tasks outlined within the overall research are successfully concluded.

A correct and suitable draft of each of the proposed procedures has been achieved, as well as the updated development of a valid and objective general coding system for each of the work units associated with the different construction cost databases in the Spanish territory.

Through the definition of tasks, which are divided into n1 (level) and n2 (sublevel), the standardization processes are scheduled during the execution of the unit, allowing for a suitable systematization for the correct inclusion of information in the Occupational Risk Prevention Plan for those organizations that choose to include safe work procedures for the units.

With the designation of the work typology, in relation to the fieldwork prior to desk work, the results have concluded with the proper identification of risks originating in each of the procedures, all thanks to on-site data collection at the investigated workplaces. Alongside photographic and visual support, the optimization of evaluation processes has been achieved, enabling full awareness of the positions, efforts, or forced movements maintained by different trades. The implementation of each preventive measure has contributed to reducing or eliminating the risks associated with each work procedure.

Once the individualized analyses of the possible work units have been proposed, statistical comparisons are made in which, after presenting the data and numbers, the elimination of or reduction in the level of each of the risks that have arisen during the task execution is confirmed. It is established that safety risks undergo a high percentage of elimination, surpassing, in most cases, 70%, or at least the reduction in the risk level for those safety risks that have not been completely eliminated. This reflects that it is a favourable measure since the reduced risk levels for the most part do not pose a risk to the worker.

When it comes to ergonomic risks, elimination faces greater persistence compared to safety risks, as approximately 50% of the risks that emerged are eliminated. The remaining percentage is retained but with a very significant reduction in the risk level for the worker.

As a note on the analysis, it is demonstrated that the technical factor associated with safety risks can be almost entirely controlled by technicians, unlike the human factor associated with ergonomic and/or psychosocial risks, which can lead to various repercussions that may arise at undetermined times and outside the scope of the work activity during the execution process. However, despite these uncontrollable factors, the numbers support the positivity and achievement of preventive improvements prioritizing the safety of each worker.

Once the conclusions have been stated, the limitations found during the investigation of the line of work must be mentioned, since, as indicated at the beginning, the line is based on other previous and large-volume investigations due to the diversity of work units existing in cost bases. The main limitations are as follows:

- Few research studies are related to the standardization of work processes in the construction sector.
- There is a large number of work units subject to standardization, which makes total application to the entire existing base difficult.
- Regarding the applicable regulations, there is a diversity of texts since the laws that affect risk prevention are totally different in each country of use.
- Construction companies do not unify work methods, establishing their own methodologies as their own trademark.
- The subjectivity of the risk assessment technician when defining the level of risk existing in the work phase.

Finally, after confirming the simplicity with which the research offers to complement different units that reinforce and consolidate primary research, some of the possible work methodologies can be highlighted to be developed in new and future lines of research:

- The drafting and definition of all the execution procedures and processes of the different work units included in the reference cost base.

- The presentation of projects related to methods for the proper implementation of the processes studied within companies in the sector.
- The implementation of computer tools and applications that allow agile access to workers who execute the tasks of each of the phases in an easy and visual way.
- The reaction of specific manuals for each of the work units with graphic diagrams and summaries of the procedures to be used.
- A comparative bank of the results before and after the standardization of work processes and procedures.
- The creation of a specific coding governed by the standard with a global commitment to use and nomenclature.

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Abbreviations

The following abbreviations are used in this manuscript:

A	Loud
ACCB	Andalusian Construction Cost Base
Ag	Hold
An	Forearms
B	Acceptable
B	Casualty
Br	Arms
C	Neck
CIEC	Construction Information and Economics Centre in the Canary Islands
COAAT	Official College of Quantity Surveyors and Technical Architects
COPSOQ	Copenhagen Psychosocial Questionnaire
D	Deficient
EC	Continued
EE	Sporadic
EF	Frequent
EO	Occasional
EU	European Union
F	Strength
FACEA	Asturias Building Quality Studies Foundation
G	Serious
G2	Group of Two
ILO	International Labor Organization
INSST	National Institute of Safety and Health at Work
ITEC	Technological Institute of Building of Catalonia
L	Lightweight

M	Improvable
M	Medium
M	Mortal or Catastrophic
M	Wrists
MA	Very high
MD	Musculoskeletal disorders
MD	Very deficient
MG	Very serious
NC	Consequence level
ND	Level of deficiency
NE	Exposure level
NI	Level of intervention
NP	Probability level
NR	Risk level
NTP	Prevention Technical Note
OWAS	Ovako Working Analysis System
P	Legs
PA	Group A Score
Pac	Activity Points
PB	Group B Score
PF	Final score
REBA	Rapid Entire Body Assessment
RL	Risk level
RULA	Rapid Upper Limb Assessment
SDG	Sustainable Development Goals
T	Torso
TA	Total A
TAM	Total accidents with mortality
TB	Total B
TC	Total C

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