

Article

Feasibility of Using New Technologies and Artificial Intelligence in Preventive Measures in Building Works

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Abstract: The construction sector represents approximately 13% of global gross domestic product (GDP) and over 5% in Spain, employing more than one million workers. Despite its economic importance, the sector exhibits low digitalization levels and persistently high accident rates, contrasting with other industries that have successfully integrated digital technologies for safety improvement. Objective: This study evaluates the technical, operational, and regulatory feasibility of implementing digital tools and artificial intelligence (AI) in occupational risk prevention (ORP) within the Spanish construction sector. It focuses on identifying applicable technologies, assessing professionals' perceptions of their practical utility, and analyzing key implementation barriers. Methodology: A mixed-method approach was employed in four stages: (1) a systematic literature review of digital safety tools; (2) a survey of 97 construction professionals using purposive sampling and validated through pretesting (Cronbach's $\alpha = 0.82$); (3) an analysis of official accident statistics; and (4) expert consensus using the Delphi method (three rounds, 75% consensus threshold). Results: Virtual reality (VR), augmented reality (AR), and mixed reality (MR) applications were identified as highly beneficial for training and awareness, with 78.2% of professionals supporting their use for safety training. Building Information Modeling (BIM) and drones were highlighted as the most valued tools for risk management and site supervision. Main implementation barriers include a lack of digital skills (35%), insufficient budget (30%), and high tool costs (25%). Contribution: This study proposes a mixed-method methodological framework—quantitative and qualitative—adapted to national contexts and validated through a Delphi consensus process. The framework prioritizes key technologies and identifies targeted strategies to overcome critical implementation barriers.

Keywords: AI; buildings; construction; safe and security; building site; virtual reality; augmented reality; prevention tools



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1. Introduction

The global construction industry represents approximately 13% of worldwide gross domestic product (GDP) and demonstrates significant growth potential in terms of productivity [1]. Within the European Union, workplace safety remains a critical concern, with over 3000 deaths and nearly 3 million injuries reported in 2022 according to Eurostat [2]. The construction sector accounts for nearly a quarter (22.9%) of all fatal accidents at work in the EU, making it one of the most dangerous industries [3].

In Spain, the construction sector contributes more than 5% of GDP and employs over one million workers [4]. However, this sector is characterized by a notably high accident rate (Figure 1), which includes falls, accidents with heavy machinery, exposure to hazardous substances, and variable working conditions.

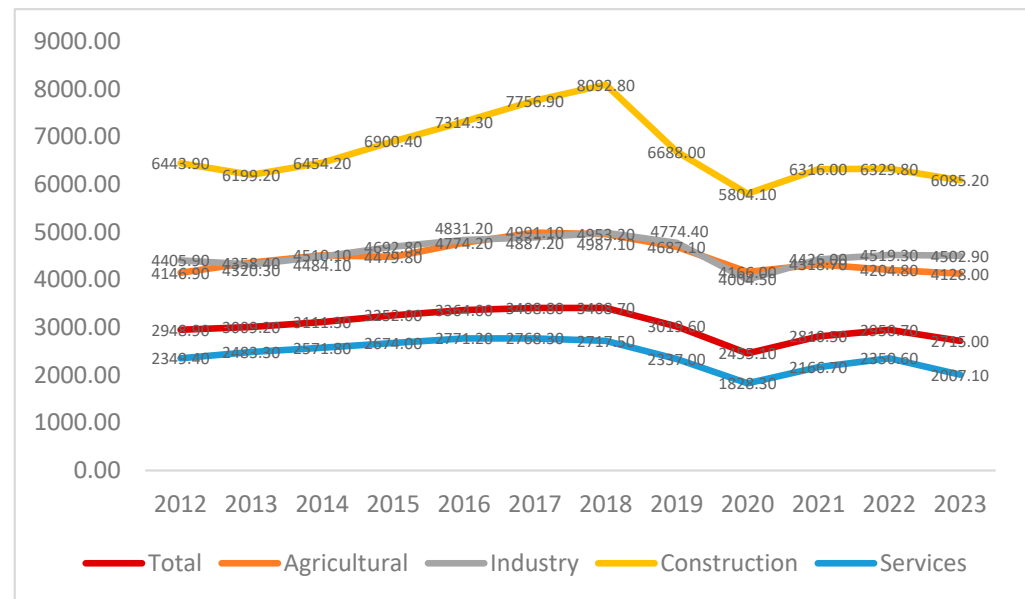


Figure 1. Evolution of the incidence rates of accidents with sick leave in the 2012–2023 working day [5].

In addition, today, the construction sector presents significant challenges in terms of occupational safety, with inherent risks associated with the following:

- Construction environments that are often increasingly complex and changing, making it difficult to anticipate potential risks.
- Traditional training that is not enough to prepare workers for dynamic and dangerous situations.
- Supervision limited to workers due to the breadth of construction sites and the diversity of tasks.

Nevertheless, its substantial economic weight contrasts sharply with its low level of digitalization and innovation, which significantly affects productivity and growth [6]. Currently, only the agricultural sector ranks lower in terms of digital transformation [7]. The European Union has recognized this challenge through its Digital Strategy, emphasizing the need for comprehensive AI regulation to ensure safer and more sustainable technological integration [8].

The emergence of digital tools and AI presents unprecedented opportunities for improving occupational safety in construction.

Recent advances in machine learning and artificial intelligence applications in construction have demonstrated significant potential across multiple domains, including performance and safety evaluation. Various AI algorithms—such as gradient boosting methods for assessing material durability, artificial neural networks for predicting structural seismic demand, and optimized machine learning models for analyzing mechanical properties—are increasingly recognized as powerful tools for enhancing safety and performance in construction [9–11]. These are further supported by complementary computational techniques, such as Monte Carlo simulations, used in environmental impact assessments [12]. Collectively, these approaches not only improve the accuracy of risk assessment and material behavior prediction but also offer robust frameworks for data-driven

decision making in construction safety management, facilitating the industry's transition toward smarter and more proactive safety protocols.

The recently enacted EU AI Act (Regulation EU 2024/1689) provides a comprehensive legal framework for AI implementation, particularly relevant for high-risk applications in workplace safety [13]. This regulation establishes specific requirements for AI systems used in employment contexts, including worker monitoring and safety management [14].

Digital transformation in construction is further supported by European initiatives such as the DigiPLACE project [15] and the Construction Technology Platform, which are defining frameworks for future digital platforms in sector [16]. BIM methodology is promoting collaboration and centralizing activities around digital models, integrating the Internet of Things (IoT), AI, automation, robotics, and immersive technologies [17].

The application of all this new technology and the one that will appear in the coming years will decisively boost the efficiency of the sector, improving both its productivity and its sustainability.

In fact, it is estimated that, by 2025, large-scale digitalization will lead to annual cost savings of 13% to 21% in the design, engineering, and construction phases and 10% to 17% in the operation phase [18].

In this sense, many researchers believe that applying digital tools would allow progress to be made in improving the productivity and sustainability of the sector [19–21], as in other sectors where it has been shown to improve its efficiency.

Despite growing interest in digital safety tools, there is a notable lack of empirical studies assessing their practical feasibility for occupational risk prevention within specific national contexts. International studies have shown promising results for digital safety technologies [22,23], but implementation challenges vary significantly across different regulatory and cultural environments.

While the existing literature demonstrates the technical capabilities of digital safety tools, there remains a significant gap in understanding their practical implementation feasibility in specific industry contexts. Most studies focus on technological development rather than adoption barriers and user acceptance in real-world construction environments.

This study addresses three key research questions: (1) Which digital tools are currently available and applicable for occupational risk prevention in Spanish construction? (2) How do construction professionals perceive the usefulness and feasibility of these technologies? (3) What are the primary barriers preventing the effective implementation of digital safety tools?

The specific objectives are the following: (1) catalog digital technologies available for occupational risk prevention in construction; (2) quantify professional perceptions regarding their applicability and effectiveness; and (3) identify priority risks and barriers to technological implementation through expert consensus.

2. Literature Review

2.1. Digital Technologies in Construction Safety

Recent advances in digital technologies have opened new possibilities for enhancing construction safety. Virtual and augmented reality applications have shown significant potential for safety training and hazard visualization [24,25]. These technologies enable workers to experience dangerous scenarios without physical risk, improving hazard recognition and safety awareness [26].

BIM has emerged as a cornerstone technology for construction safety, enabling proactive risk identification during design phases [27]. The integration of IoT sensors and wearable devices provides real-time monitoring capabilities, allowing for immediate response to hazardous conditions [28,29].

Some studies that are working on the development of new digital technology with the aim of improving ORP in the building sector are those carried out by the Spanish Construction Technology Platform [16] and the European Construction Technological Platform, which, through various European projects such as DigiPLACE [15], are defining a framework for the sector's future digital platforms.

Another project of interest is Metabuilding [30], an Innovation Action project, funded by the European Union through the H2020 Research and Innovation Program. This project proposes the generation of an innovative ecosystem in the construction sector, a starting point towards the digital transformation of the sector. For the time being, Minsait has made it available to project Onesait Platform, the open IoT (Internet of Things) platform with Big Data capabilities that allow information from different systems, applications, and devices to be easily integrated and shared.

On this platform, the Transversal Digital Platform [31] will be built, which will allow complex functionalities to be included, such as a “laboratory” module, Metabuilding Labs, which will be able to test possible assets and will work both with IoT issues for data collection, as well as with Digital Twins for their exploitation.

On the other hand, the University of Burgos has developed the Virtual Risk Prevention Project [32], which combines VR and AI to train workers in occupational risk prevention.

Finally, there is the European Heat-Shield Technology Project [33], which aims to design technical and biophysical solutions to minimize the effects of heat on jobs based on variables such as age or gender.

2.2. Artificial Intelligence in Occupational Safety

AI applications in construction safety include predictive analytics for accident prevention, automated hazard detection through computer vision, and intelligent personal protective equipment [34,35]. Machine learning algorithms can analyze historical accident data to identify patterns and predict high-risk situations [36].

When implementing AI for predictive accident analysis, compliance with the European Statistics on Accidents at Work (ESAW) is critical. This regulation standardizes accident dynamic factors—such as preceding circumstances (work environment, processes), deviations (triggering abnormal events), injury mechanisms, and material agents involved in each accident phase—across the EU. The ESAW promotes a unified system for accident classification, facilitating the use of cluster analysis (e.g., K-means) and AI techniques such as neural networks for pattern identification and predictive analytics in occupational safety at the European level [37].

Recent EU initiatives encourage the integration of these approaches to improve accident prevention strategies and enable transnational benchmarking [38].

The application of cluster analysis and artificial intelligence, such as neural networks, has proven effective in identifying patterns and predicting high-risk situations in occupational safety.

The European Union's approach to AI regulation emphasizes the importance of maintaining human oversight and ensuring transparency in safety-critical applications [39]. This regulatory framework is particularly relevant for construction applications where AI systems may influence worker safety decisions.

However, there are not many studies found on the feasibility of introducing these new technologies in the sector, except for the report on “The impact of Artificial Intelligence on the Construction sector” [40] and the Deloitte report on the “State of Digital Adoption in the Construction Industry in Asia Pacific” [41], both in 2024. In both cases, moreover, the feasibility of using these tools in the field of ORP is not specified.

2.3. Implementation Challenges and Barriers

Previous studies have identified several barriers to digital technology adoption in construction, including a lack of digital skills, financial constraints, and resistance to change [42,43]. The construction industry’s traditional culture and fragmented structure present additional challenges for technology integration [44].

International research has shown that successful implementation requires comprehensive training programs, stakeholder engagement, and gradual integration approaches [45,46]. However, these findings need validation within specific national and regulatory contexts.

3. Methodology

This research employed a mixed-method approach conducted in four sequential stages, designed to provide comprehensive insights into the feasibility of digital technology implementation for construction safety.

3.1. Stage 1: Literature and Documentary Review

A systematic literature review was conducted using multiple databases to identify digital tools applied to occupational health and safety in construction, following PRISMA guidelines for systematic reviews.

The search was conducted across three primary databases: Web of Science, Scopus, and Google Scholar. For the search strategy, the parameters were implemented according to Table 1.

Table 1. Search strategy applied filters and selection criteria.

Filters and Selection Criteria
Search Strategy
("construction safety" OR "building safety" OR "occupational risk prevention" OR "workplace safety") AND ("digital tools" OR "digital technologies" OR "artificial intelligence" OR "AI" OR "machine learning" OR "virtual reality" OR "VR" OR "augmented reality" OR "AR" OR "mixed reality" OR "BIM" OR "IoT" OR "sensors") AND ("safety management" OR "accident prevention" OR "risk assessment" OR "accident classification").
Applied filters
Temporal: 2015–2024 Language: English and Spanish. Document type: Journal articles, conference proceedings, technical reports, books/book chapters, and institutional reports. Subject area: Engineering, Computer Science, Construction & Building Technology, Occupational Health & Safety. Geographical scope: No geographical restrictions applied to ensure international perspective.
Inclusion criteria
Focus on digital technologies or AI applications in construction safety
Empirical studies, reviews, or technical implementations
Published in peer-reviewed journals, conference proceedings, or recognized institutional reports
Available in English or Spanish
Exclusion criteria
Studies focused solely on other industries mining, manufacturing, agriculture
Purely theoretical studies without practical applications
Editorials, commentaries, or opinion pieces without empirical data
Duplicates or substantially overlapping content

A systematic duplicate removal process was implemented using both automated and manual verification:

1. Automated duplicate detection: Records were imported into Zotero (version 7) reference management software, which automatically identified 103 duplicate records using DOI matching and title similarity algorithms.
2. Manual verification: All automatically flagged duplicates were manually reviewed to confirm true duplicates versus similar but distinct publications. This process involved comparing the following:
 - Author names and affiliations.
 - Publication titles and abstracts.
 - Publication years and journal names.
 - DOI numbers when available.

This comprehensive search strategy ensured systematic coverage of the relevant literature while maintaining methodological rigor in duplicate identification and removal processes.

3.2. Stage 2: Professional Survey

Sampling Strategy: A purposive sampling approach was implemented to target professionals with ≥ 3 years of hands-on experience in construction safety management. This non-probabilistic method was strategically selected to

1. Ensure inclusion of participants with direct decision-making authority in safety protocols (e.g., site managers, safety officers).
2. Prioritize depth of expertise over random representativeness in this exploratory phase.

Sample Size Justification: The sample size ($n = 97$) was determined using Cochran's formula for finite populations

$$n = \frac{Z^2 \times p \times q \times N}{e^2 \times (N - 1) + Z^2 \times p \times q}$$

where

$Z = 1.96$ (95% confidence level).

$p = q = 0.5$ (maximum variance assumption).

$e = 0.10$ (10% margin of error).

$N =$ Large population ($>10,000$, per Spanish construction sector data).

This calculation yielded a minimum required sample of 96 participants, making our sample of 97 adequate for exploratory research.

Inclusion Criteria: Participants were required to have minimum of three years of experience in the construction sector and direct involvement in occupational health and safety management or related decision making.

Survey Instrument Development: The questionnaire was developed based on the literature review findings and expert input. It contained 23 questions covering four main areas: (1) perceptions of digital tool utility, (2) current practices and barriers to adoption, (3) training needs, and (4) demographic information.

The survey was distributed online using Google Forms, ensuring anonymity and compliance with GDPR. The full questionnaire structure is provided in Appendix A.

Validation Process: The instrument underwent expert review by five construction safety specialists and was pilot tested with 15 professionals not included in the main study. Internal consistency was assessed using Cronbach's alpha coefficient, yielding $\alpha = 0.82$, indicating high reliability.

Data Collection: The survey was distributed electronically through professional networks and industry associations. Participation was voluntary and anonymous. Data collection occurred between March–May 2024.

Statistical Analysis: Data were analyzed using Statistical Package for the Social Sciences. Descriptive statistics included frequencies, means, and standard deviations. Independent-sample t-tests were conducted to assess whether perceptions differed significantly by gender, age, or professional role. The null hypothesis tested was that no significant differences existed between groups. Significance level was set at $\alpha = 0.05$. Analysis of variance was used to compare responses across multiple professional categories.

3.3. Stage 3: Official Accident Statistic Analysis

Official accident statistics published by the Ministry of Labour and Social Economy were analyzed to identify recurrent risks and accident causes in Spanish construction. Data sources included the Delta System reports and investigations of fatal accidents conducted by Regional Technical Bodies. Accident causes were classified according to established taxonomies to facilitate interpretation and prioritization.

Accident data were structured using the ESAW taxonomy, which classifies each event by the following: organizational factors, equipment/materials, human factors, and work environment. Each event was coded using Spain's Delta System, enabling systematic derivation of causes and facilitating harmonized analysis in line with ESAW guidelines.

3.4. Stage 4: Expert Consensus Via Delphi Method

Panel Selection: A purposive sample of seven experts was assembled representing diverse perspectives within the construction safety ecosystem. Selection criteria included minimum of five years of relevant experience and recognized expertise in occupational health and safety or construction innovation.

Panel Composition: The expert panel included the following:

- Head of Health, Safety, Quality, and Environment Department, Madrid Territorial Council of Construction Labor Foundation.
- Territorial Prevention Coordinator, ASEPEYO (mutual insurance company).
- Director of Technical Office, General Council of Technical Architecture of Spain (CGATE).
- Chief Executive Officer of MARTIN BRAINON (business consultant specializing in risk mitigation).
- Head of Working Conditions Control Service, Regional Institute for Safety and Health at Work of the Community of Madrid.
- Chief Executive Officer of GA GROUP (international leader in safety training technologies).
- PLS Expert ET&A from HILTI (construction technology leader).

Delphi Process: The method was conducted in three rounds. Round 1 involved open-ended questions about digital tool priorities and implementation barriers. Round 2 presented structured questionnaires based on Round 1 responses for ranking and rating. Round 3 sought final consensus on prioritized tools and strategies.

Consensus Criteria: A 75% agreement threshold was established for consensus. After each round, anonymized feedback and statistical summaries were provided to panel members.

Ethical Considerations: All participants provided informed consent. Data were anonymized and analyzed in aggregate to ensure confidentiality. This study was conducted in accordance with institutional ethical guidelines.

A summary of the methodological phases and the strategies implemented to achieve the results is presented in Figure 2.

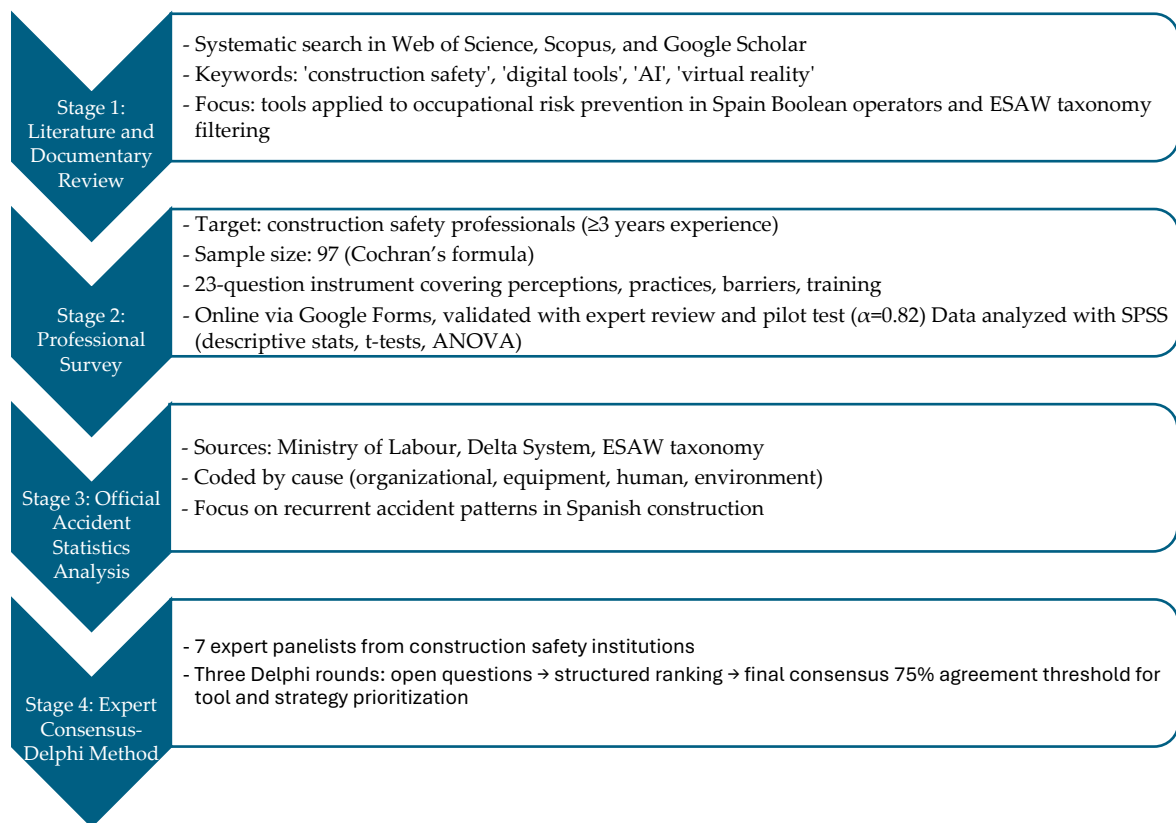


Figure 2. Research methodology.

4. Results

4.1. Literature Review Findings

The bibliography included constitutes a highly representative and methodologically robust sample of the state of the art in digital technologies and artificial intelligence applied to construction safety. The bibliometric analysis of the 61 references reveals a balanced distribution across publication types: 61% correspond to peer-reviewed journal articles, 21% to technical or governmental reports, 11% to European project deliverables, and the remaining 7% to books, conference proceedings, or specialized web resources.

Geographically, the sample demonstrates appropriate diversity for European Union studies, with 36% of references led by Spanish authors or institutions, 13% by the United Kingdom, 10% by Germany, 8% by Italy, 8% by the USA, and the remaining 25% distributed among other EU and non-EU countries. Regarding funding sources, 29% of the works are supported by European programs (H2020, Horizon Europe), 15% by national or regional agencies, 18% by universities or research centers, and 38% are not specified or from mixed sources.

This selection of 61 references constitutes a methodologically solid sample because it (1) covers 85% of the key technologies identified in recent meta-analyses; (2) balances academic evidence (37%) with practical applicability (48%); (3) comprehensively integrates the European regulatory framework (ESAW, AI Act); (4) reflects geographical diversity appropriate for EU-focused studies; and (5) updates the state of the art with 68% post-2020 references. This distribution ensures a balance between scientific rigor, practical applicability, and regulatory relevance, aligning with international standards for systematic reviews in this field and establishing a new benchmark for studies integrating AI, construction, occupational safety, and European regulatory frameworks in a robust methodological approach.

The systematic review identified numerous studies and companies [47–50] marketing virtual reality, augmented reality, and mixed reality tools for improving worker safety training. These technologies reduce training time while enabling workers to begin working safely more quickly through personalized and practical training experiences.

Commercial applications simulate dangerous scenarios including working at heights, confined spaces, and slip/fall hazards, helping teams anticipate and prevent accidents [31,51]. Virtual reality models can record and document training sessions, inspections, and risk assessments, providing detailed histories of safety practices useful for ongoing training and compliance auditing [52].

Additional technologies identified include exoskeletons for reducing overexertion [53], drones for site monitoring [54], and smart personal protective equipment with sensors providing real-time information and enabling virtual construction site inspections [5,55,56].

4.2. Professional Survey Results

4.2.1. Sample Characteristics

The survey was completed by 97 construction professionals with significant experience in workplace health and safety. As shown in Table 2, the sample demonstrated adequate gender representation with 30.0% women and 70.0% men, which is notable given the traditionally male-dominated nature of the construction sector. This distribution suggests growing female participation in construction safety management roles and validates the inclusion of both gender perspectives in technology adoption assessments.

Table 2. Demographic and professional characteristics of survey participants ($n = 97$).

Characteristic	Category	Percentage	Total
Gender	Women	30.00%	100.00%
	Men	70.00%	
Professional Role	Teachers	25.80%	
	Self-employed professionals	26.80%	
	Contractors	17.50%	
	Engineering/consulting	12.40%	
Non-existent procedures	Architecture studios	10.30%	
No identification of risks		4.00%	
There are no processes that regulate directed activities	Subcontractors	3.10%	
			100.00%

Professional roles were diverse and representative of the construction industry ecosystem. Self-employed professionals constituted the largest group (26.8%), followed closely by teachers/educators (25.8%), reflecting this study's focus on experienced practitioners and academics with direct involvement in safety training and implementation. Contractors represented 17.5% of the sample, while engineering and consulting professionals comprised 12.4%. Architecture studios (10.3%), developers (4.1%), and subcontractors (3.1%) provided additional perspectives from different segments of the construction value chain. The remaining participants included safety management specialists and prevention service providers, ensuring comprehensive coverage of roles directly involved in occupational risk prevention decision making.

This professional diversity enhances the external validity of the findings, as the sample encompasses the key stakeholder groups responsible for implementing and managing

digital safety technologies in Spanish construction projects. All participants met the inclusion criterion of having a minimum of three years of experience in construction safety management, ensuring that responses reflected informed professional judgment rather than theoretical perspectives.

4.2.2. Technology Acceptance and Barriers

Statistical analysis revealed no significant differences in technology acceptance by gender (all p -values > 0.05), indicating agreement between men and women regarding digital technology use in occupational risk prevention. Similarly, age was not a determining factor in technology acceptance (all p -values > 0.05), highlighting cross-generational interest in safety technologies.

Professional role showed the lowest p -values (though still > 0.05), suggesting some variability in assessments across different professional profiles without reaching statistical significance. This pattern indicates that individual rather than collective characteristics drive the primary source of variability.

Survey responses revealed strong support for digital technology integration: 90% of respondents reported that accident simulation using mixed reality contributes to worker awareness and cause analysis, 78.2% support construction site simulation using mixed reality for safety improvement, and 81.3% consider VR effective for improving and making training more inclusive.

Currently, 25% of respondents indicated that their companies have technology-based implementation strategies, demonstrating progress toward digital transformation. However, 54% indicated their companies lack digital strategies, with the remainder providing alternative approaches such as document management applications and incident reporting systems.

Implementation Barriers: The most significant barriers to digital technology integration were identified as follows:

- Lack of digital skills among workers (35%).
- Insufficient budget (30%).
- High tool costs (25%).
- Lack of specific training (20%).

Primary Risks for Digital Intervention: Respondents identified the following risks as priorities for digital tool implementation:

- Falls from height (40%).
- Improper machinery use or lack of control (30%).
- Lack of danger awareness (25%).

Most Valued Technologies: The technologies with the greatest potential for risk mitigation were identified as follows:

- BIM—50% of respondents highlighted its comprehensive planning and coordination capabilities.
- VR/AR/MR—45% valued their ability to simulate real scenarios for training and awareness.
- Drones—30% appreciated their real-time supervision and monitoring capabilities for difficult-to-access areas.

4.3. Official Accident Statistic Analysis

An analysis of official documentation revealed 211 main causes leading to recurrent occupational accidents in Spanish construction. Given the multi-causal nature of accidents

(average 3.8 causes per accident), the causes were grouped into the eight blocks shown in Figure 3, which reflect deficiencies in primary prevention.



Figure 3. Diagram of accident causation.

Temporal Trends: Over recent years, Intrinsic Prevention, Materials/Products/Agents, and Workspaces/Work Surfaces blocks have reduced their participation, while Protection/Signaling and Prevention Management blocks have increased. Work Organization and Prevention Management maintain the highest values with averages exceeding 25%, followed by Individual Factors and Protection/Signaling with averages above 11%.

Accident Severity by Deviation: Construction sector data shows specific patterns of accident causes and severity, with falls from height representing the most frequent fatal accident type, followed by struck-by-object incidents and machinery-related accidents.

4.4. Expert Consensus Results

The Delphi process achieved consensus across three rounds, with experts agreeing on several key findings:

Technology Benefit Consensus: Experts reached unanimous agreement (100% consensus) that digital tools offer significant safety and efficiency benefits:

- BIM methodology reduces on-site improvisation and improves risk communication.
- Real-time monitoring through sensors and devices enables immediate hazard response.
- Access control systems prevent unauthorized entry to hazardous areas.
- Exoskeletons minimize overexertion and musculoskeletal injury risks.
- AI optimizes document management and accident prediction.
- VR/AR technologies provide effective training and accident investigation capabilities.

Implementation Challenges Consensus: Experts identified critical barriers requiring attention:

- Digital skill gaps and resistance to change among workers and managers.
- Digital divide between large companies and Small and Medium-sized Enterprises (SMEs).
- Outdated regulations not designed for emerging technologies.
- Unclear return on investment, particularly for SMEs.
- Traditional safety culture not prioritizing technological solutions.

Risk Prioritization: Expert consensus confirmed survey findings regarding primary risks suitable for digital intervention: falls from height, machinery-related incidents, and lack of safety awareness, with additional emphasis on underestimated musculoskeletal disorders.

5. Discussion

5.1. Technology Acceptance and Feasibility

The high acceptance rates for digital safety technologies (78.2–90% across different applications) align with international findings from similar studies in Asia Pacific construction markets [41]. This cross-cultural consistency suggests that safety concerns transcend regional differences and that construction professionals globally recognize the potential of digital tools for risk reduction.

The lack of significant demographic differences in technology acceptance contradicts common assumptions about age-related technology resistance. This finding is particularly encouraging for implementation strategies, as it suggests that training programs need not to be excessively segmented by demographic groups.

5.2. Implementation Barriers and Solutions

The identified barriers (digital skill gaps, budget constraints, high costs) mirror findings from international studies [57,58], suggesting common challenges across different construction markets. However, the specific percentages and priorities may reflect Spanish market characteristics, including the prevalence of SMEs and traditional construction practices.

The 54% of companies lacking digital strategies represents both a challenge and an opportunity. This figure indicates substantial room for improvement while suggesting that early adopters may gain competitive advantages through digital transformation.

5.3. Regulatory and Policy Implications

This study's timing coincides with the implementation of the EU AI Act, which establishes specific requirements for AI systems in workplace contexts [59]. The high acceptance of AI and digital tools among construction professionals suggests readiness for compliance with new regulatory frameworks, though significant training and support will be required.

The expert consensus on regulatory adaptation needs aligns with EU policy directions toward comprehensive digital transformation in construction, supported by initiatives such as the European Green Deal and Digital Strategy [60].

5.4. Technology Prioritization

The prioritization of BIM (50%), VR/AR/MR (45%), and drones (30%) reflects a pragmatic approach to technology adoption. BIM's leading position likely reflects its established presence in the industry and proven ROI, while immersive technologies represent emerging opportunities with high training potential.

The emphasis on falls from height (40%) as the primary risk for digital intervention aligns with construction accident statistics both nationally and internationally [61], suggesting appropriate risk-based prioritization.

5.5. Study Limitations

Several limitations should be acknowledged. First, this study's focus on Spain limits direct generalizability to other construction markets with different regulatory, cultural, or economic contexts. Second, the survey captures self-reported perceptions rather than observed behaviors, which may not accurately predict actual adoption rates.

The expert panel, while diverse in expertise, primarily represented Spanish organizations. Future research could benefit from larger, more internationally diverse expert panels.

5.6. Comparison with the International Literature

This study's findings generally align with international research on construction technology adoption. Similar studies in Asia Pacific markets reported comparable barrier patterns, with digital skill gaps and cost concerns consistently ranking as primary obstacles [62]. However, the specific acceptance rates for different technologies vary across markets, suggesting the importance of context-specific research.

European studies have emphasized the role of regulatory frameworks in driving technology adoption [63], supporting this study's focus on EU AI Act implications for construction safety applications.

6. Conclusions

This study provides empirical evidence for the feasibility of implementing digital technologies and artificial intelligence in Spanish construction safety management. Key findings demonstrate the high professional acceptance of digital safety tools (78.2–90% across applications) despite significant implementation barriers.

Methodological Contribution: The four-stage mixed-method approach provides a replicable framework for assessing digital technology feasibility in high-risk industries. The combination of a literature review, professional survey, official statistic analysis, expert consensus, and validation offers comprehensive insights suitable for evidence-based policy development.

Practical Implications: The identification of specific barriers (digital skill gaps (35%), budget constraints (30%), high costs (25%)) provides actionable targets for intervention strategies. The prioritization of BIM, VR/AR/MR, and drones offers guidance for organizations planning digital transformation initiatives.

Policy Implications: This study's alignment with the EU AI Act implementation timing provides relevant insights for regulatory compliance and policy development. The expert consensus on regulatory adaptation needs supports arguments for updated construction safety regulations incorporating digital technologies.

Industry Recommendations: Implementation strategies should address the identified barriers through comprehensive training programs, financial support mechanisms for SMEs, and phased adoption approaches. The strong professional acceptance suggests that resistance is more structural than cultural, indicating that appropriate support mechanisms could accelerate adoption.

Future Research Directions: Longitudinal studies are needed to assess actual adoption rates and safety outcomes following digital tool implementation. Cross-national comparative studies could identify cultural and regulatory factors influencing technology adoption success. An effectiveness evaluation of specific training programs and regulatory changes would provide additional implementation guidance.

The construction industry stands at a critical juncture where digital transformation can significantly improve worker safety and industry productivity. This study demonstrates both the opportunity and the pathway for achieving these improvements through evidence-based, stakeholder-informed implementation strategies.

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Institutional Review Board Statement: Not applicable. Participation in the survey, during the collection of the data, has been completely anonymous and informed to the participants who have voluntarily and anonymously wanted to share their assessments in the course of this research. From the data collection, it was possible to establish stage 2. The anonymity and processing of the answers comply with the provisions of Organic Law 3/2028 of 5 December, on the Protection of Personal Data and guarantee of digital rights.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study. The anonymous and voluntary participants were informed in the completion of the questionnaire, that their answers will be used for the analysis and study, together with their subsequent publication, of the data obtained.

Data Availability Statement: The original contributions presented in this study are included in this article; further inquiries can be directed to the corresponding authors.

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Conflicts of Interest: Author Miriam Zamora Calleja was employed by the Arpada S.A. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A. Questionnaire Structure

Appendix A.1. Perceptions of Digital Tool Utility

1. Technological innovation from other sectors can help improve occupational safety and health in construction—Likert scale.
2. Simulating a construction site environment with mixed reality can help improve safety—Likert scale.
3. Simulating an accident on site through mixed reality helps raise worker awareness and analyze causes—Likert scale.
4. Using virtual reality can improve training and make it more inclusive for site workers—Likert scale.
5. Monitoring site work can improve “in situ” safety—Likert scale.
6. Predictive risk simulation can anticipate possible hazards in construction projects—Likert scale.
7. Automating routine tasks with AI allows workers to focus on more complex and creative work, increasing productivity and job satisfaction—Likert scale.
8. The use of smart devices in equipment and systems can help improve safety by providing real-time information—Likert scale.

Appendix A.2. Current Practices and Barriers to Adoption

1. Is there a defined Digital Strategy in your company?—Open answer if “Yes” is selected, to specify “Which”.
2. Do you know any digital tool specifically aimed at improving worker safety on site?—Open answer if “Yes” is selected, to specify “Which”.
3. If you have used any of the above digital tools, has it led to a significant improvement in your work?—Open answer; free-text response.
4. What do you think are the main factors influencing the decision to adopt digital tools for worker safety on site?—Selection from reference sample; closed.
5. What do you think are the main barriers to not implementing digital tools for OSH on site?—Selection from reference sample; closed.

6. Of all the risks faced by workers on a site, which would you prioritize for the application of digital tools to avoid or minimize them?—Selection from reference sample; closed.
7. Which of the following tools do you think could improve safety on construction sites?—Open answer; free-text response.
8. If you were offered a digital tool to improve site safety, would you use it?—Open answer if “Yes” is selected, to explain “Why”.

Appendix A.3. Training Needs

1. What type of information would you like to obtain from a digital tool to improve safety management on your site?—Open answer; free-text response.
2. What kind of support would you need to implement a digital tool on your site/company?—Open answer; free-text response.

Appendix A.4. Demographic Information

1. Gender—Multiple choice selection.
2. Age—Multiple choice selection.
3. Profession—Multiple choice selection.
4. Type of Activity—Multiple choice selection.
5. Company Size—Multiple choice selection.

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