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Research article

Enhancing BIM implementation in Spanish public procurement: A framework approach

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ABSTRACT

The European Union supports the use of technology to improve public procurement, acknowledging Building Information Modeling (BIM) as a catalyst for cost-effective public works and innovation. The purpose of this paper is to evaluate BIM implementation practices in Spanish public procurement. The methodology used in this study is a mixed research method involving a questionnaire survey and semi-structured expert interviews. The findings reveal market maturity as a barrier to BIM adoption in Spanish public procurement throughout the asset lifecycle. Selecting the right instrument for implementation proves challenging for public organizations. This study has contributed to the development of more practical and effective strategies to ensure full adoption of BIM within the public procurement sector of Spain. It proposes a framework approach for the pre-contractual phase, helping contracting authorities to make the optimal instrument selection. Two criteria are considered: the maturity of the public client and sector, and the economic value classification of tenders.

1. Introduction

Many public sector organizations still focus on paper-based procurement. This leads to design problems, omissions, conflicts, calculation errors and inconsistencies [1]. On the contrary, the use of Building Information Modeling (BIM) can bring multiple advantages that translate into economic benefits, such as increased value of public funds, quality of design, collaboration, and cost and schedule certainty.

BIM implementation is at an advanced stage in countries such as Singapore, Finland, Korea, the United States, the United Kingdom and Australia [2], but its adoption in developing countries is limited. One of the reasons for this is the lack of regulations and guidelines among the parties involved in a construction project [3]. In the case of the European Union, Directive 2014/14/EU establishes that member states may require the use of electronic building design tools, but BIM is not legally binding. This has resulted in varying roles, responsibilities, contracts and procedures among countries [4].

There exists a noticeable gap in knowledge about the strategies for successfully applying the methodology during the tendering phase [5,6]. This is due to the multidisciplinary and fragmented nature of the industry. Therefore, the public sector has a key role to play in guiding the architecture, engineering, construction and operations (AECO) industry towards the adoption of BIM [7].

A major obstacle to BIM implementation is identifying the information requirements needed to support model-based project

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delivery and asset management [8]. This is achieved through the development of a country-specific implementation framework, as the adoption of the methodology has important cultural, legal, procedural and contextual dimensions [5]. Using standards is a common practice in the AECO sector, but implementing BIM requires the development of new ones [6]. An intensive increase in the use of the methodology has occurred in those countries where government agencies and non-profit organizations have promoted specific regulations, guidelines and standards for this purpose [7]. These measures have proven effective in addressing issues relating to model management and control [3].

In the specific case of Spain, 1005 tenders with BIM requirements were published during 2023, involving an investment of 3697 M€ [9]. This marks the sixth consecutive year of increasing demand for the methodology. Nevertheless, the potential for BIM implementation is estimated to reach 34.8 % of the total tender budget of the General State Administration. Despite the growing number of tenders that require BIM and the investments made in recent years, its use is not mandatory in the country, although there is a national implementation initiative. A preliminary roadmap for adopting the methodology was prepared in 2015, but successive changes in government led to stagnation. As a result, there are limited references available for drafting tenders with BIM requirements that align with a single national criterion and meet the asset's specific lifecycle needs [10]. The Interministerial BIM Commission, created by the Spanish government in 2018, is currently developing a plan to promote the integration of BIM into public procurement. This plan will encompass gradual implementation strategies, based on the use of open standards for the exchange of information, taking into account both contracting authorities and small and medium-sized enterprises (SMEs). It aims to (1) ensure technological neutrality, and (2) provide independence in the choice of technological alternatives for bidders, particularly SMEs [11]. The uniqueness of BIM implementation in Spain with respect to other countries of the European Union lies precisely in the great relevance of SMEs. They represent 99.97 % of the companies in the construction sector in the country in 2022 [12]. In Europe, BIM implementation is mainly led by large companies. However, SMEs in Spain show a lower maturity in terms of adoption of the methodology. This is mainly due to their more limited human and financial resources, which are often used in smaller and less complex projects where the need to use BIM is not perceived. SMEs in the country have in some cases a low degree of digitalization [13] and are not very receptive to innovation [14]. Other important factor is the lack of demand on the part of contracting agents, as they are unaware of the benefits of their use [15].

The main objective of this study is to assess the methods for integrating the BIM methodology into Spanish public procurement. It is conducted from the perspective of professionals in the AECO industry with knowledge and experience in both BIM and tendering processes. Additionally, it aims to determine the significance attributed to various aspects, including BIM requirements, standards and roles or functions. The document proposes a framework for the pre-contracting phase intended for public administrations and contracting authorities. This framework identifies diverse instruments for integrating the methodology into public contracts and simplifies the selection of the most suitable one.

2. Literature review

BIM implementation directly affects project management processes and the benefits of its use are reflected in all stages of the asset lifecycle [16]. Some public sector organizations do not realize their potential to control how a project is designed, as they are unaware of the contractual requirements for BIM adoption [17]. The lack of a precise definition of these requirements and their inclusion in the contractual documents is an obstacle to project development [18]. In the long term, professionals with the knowledge and desire to use the methodology often revert to traditional methods to align with industry demand trends [19,20].

Several researchers have examined the barriers to BIM adoption. Manzoor et al. [21] explored and developed strategies to mitigate the existing barriers in developing countries. They conducted a survey within the Malaysian construction industry involving various stakeholders in a project. Participants highlighted five main barriers to introducing the methodology: lack of standards and guidelines, lack of training in BIM, lack of expertise, high costs and lack of research. Ademci & Gundes (2018) performed an analysis of the existing literature on barriers to BIM implementation. The lack of industry standards and strategies was mentioned as a prominent issue. The authors pointed out that many of the BIM standards developed and implemented in several countries are not practical or effective. Olanrewaju et al. (2020) carried out a similar analysis within the context of the Nigerian construction industry. They identified non-existent or inadequate government policies, insufficient contractual coordination or lack of knowledge as major barriers to BIM adoption. The lack of government leadership was also highlighted as a critical issue by Zhou et al. [22] and Gamil & Rahman [23], referring to the construction industries of China and Yemen, respectively. Related to this last barrier are the traditional procurement methods, which are not adapted to the needs of BIM. This was identified as a significant obstacle in the research conducted by Youkhanna Zaia et al. [24] on the level of BIM in the Iraqi construction industry. In the case of the European Union, according to Charef et al. [25], the most prominent barriers include a lack of qualified personnel, the absence of BIM-related training in universities, resistance to change, and a lack of guidance for BIM implementation. The authors further noted that these issues lead to a fragmented market, underscoring the need for a standardized approach to bridge the gap.

Another important aspect to analyze is how contracts with BIM requirements are applied in practice and their impact on stakeholders' use of the methodology. Only reducing barriers will not guarantee the adoption of BIM. It is important to choose tactics for its implementation carefully to remove initial barriers and promote acceptance of the methodology [26]. Owners can promote BIM implementation by incorporating specific criteria into the contractor selection process, establishing a network of qualified BIM service providers, adjusting deliverable requirements to include the model information's scope, detail, and organization, and proposing performance-based contracts and shared incentive schemes [27]. A survey conducted with owners in North America on BIM adoption and its value found that better definition of BIM deliverables among stakeholders is a key factor in increasing the benefits of its use [28]. In this context, Zima & Mitera-Kiełbasa [29] presented a case study on the preparation and management of BIM models in the design and construction of three large public sector projects in Poland. It addressed the three areas that constitute Exchange

Information Requirements (EIR): technical, management and strategic. The aim was to simplify the definition of the information requirements for future construction projects using BIM. Hafeez et al. [30] explored the application of EIRs in Qatar's construction projects. The paper examined current BIM practices in the country through interviews with key industry players. Based on their findings, they proposed country-specific EIR and developed a set of implementation guidelines.

The above information identifies the lack of governmental standards and strategies as a significant obstacle to the development of projects with BIM requirements. The public sector has a high potential to serve as a driving force for the inclusion of this methodology. Consequently, the establishment of a comprehensive national-level BIM standard, along with appropriate contractual guidelines, is crucial for its successful implementation.

3. Methodology

This research addresses the inclusion of information requirements in public procurement processes in Spain. It employed a mixed-method approach, including a questionnaire and semi-structured interviews with BIM experts from the AECO industry with knowledge of Spanish tendering.

The study was divided into two phases, as illustrated in Fig. 1. In the initial phase, a literature review on the contractual aspects influencing BIM adoption was conducted, along with an analysis of BIM tendering in Spain and the various methods of including information requirements in contracts. A survey was carried out to determine the professional profile of the participating BIM experts, considering their academic background, BIM knowledge, workplace, years of work experience and specialization (e.g., buildings, infrastructure, design, construction, etc.).

The second phase consisted of semi-structured interviews conducted via video call during the months of June–July 2022. The participants evaluated the current methods for incorporating BIM methodology in Spanish public sector contracts and the importance of specific BIM requirements. Each was assigned a case study and answered a standardized set of questions hosted on an online survey platform. The questions were the same for all respondents, but the proposed case study varied depending on their professional backgrounds.

3.1. Selected tenders as case studies

An analysis of the tenders published in the Spanish public sector during the period 2018–2022 was performed. In the country's public procurement contracts, three mechanisms can be employed to incorporate BIM: technical solvency (I1), award criteria (I2), and contract extras (I3). These instruments are governed by Law 9/2017, on Spanish Public Sector Contracts. While there is no

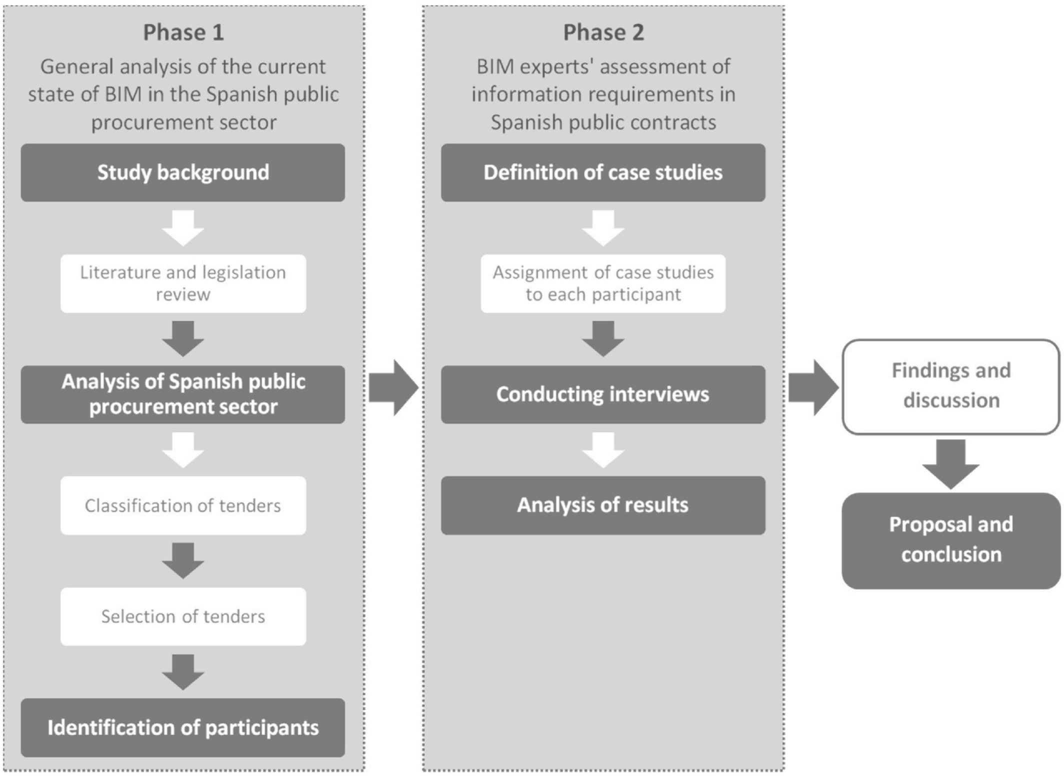

Fig. 1. Methodological flow chart.

predetermined criterion for choosing one over another, the selection typically depends on factors such as the maturity of the sector, the contracting administration and the potential bidders for a specific contract, as well as its economic value. The successful execution of BIM projects will largely depend on the selection of the right instrument.

Technical solvency (I1) refers to the minimum and excluding conditions established by the contracting authority to ensure that the successful bidder has the necessary capabilities to fulfil the contract. To demonstrate the bidder's BIM technical solvency, it is usual to require a list of projects completed with BIM requirements within the past few years. The award criteria (I2) are guidelines to evaluate the submitted bids. These criteria are determined by the contracting authority, and the score assigned to each of them depends on the evaluation conducted by those responsible for bid analysis. Examples of award criteria related to the methodology include the submission of a BIM Execution Plan and the experience or training in BIM of the personnel proposed for contract development, among others. Contract extras (I3) are additional services to those defined in the contract. This method of requiring the use of the methodology is typically common in sectors and administrations with a low level of BIM maturity.

A total of 1547 tenders were collected and classified according to the type and category they belong to. The 'type' refers to whether the tender is in the field of building or infrastructure, while the 'category' classifies them depending on their economic value. The classification by economic value facilitated the selection of the most relevant tenders in the sample analyzed. In general, contracts with higher investment volumes tend to have a better definition of BIM requirements and a higher level of development. The categories range from contracts under 150,000 € (category 1) to those over 5 M€ (category 6), with intermediate levels for contracts between 150,000 and 360,000 (category 2), 360,000 and 840,000 (category 3), 840,000 and 2,400,000 (category 4) and 2,400,000 and 5,000,000 (category 5).

Those tenders with a higher level of development and detail were selected to prepare 17 case studies for the second phase of the research. These included 4 sample tenders from the building sector, 11 from civil engineering, and 2 related to mechanical and electrical facilities. The larger number of cases proposed for civil infrastructure reflects the diversity of projects in this area (e.g. large structures, railways, roads, etc.). Table 1 provides an example of the developed case studies.

3.2. Expert demographics

Professionals with valuable experience in the construction sector and a strong commitment to the BIM methodology were contacted via email, resulting in a sample size of 34 respondents. Twelve had a background in architecture, another 12 in civil engineering, 4 in industrial engineering, and the remaining 6 had other technical backgrounds.

Among the respondents, 53 % had worked exclusively on design phase projects in the last 5 years, 6 % on construction phase projects, and 41 % had experience on both. On the other hand, 16 % had participated in drafting tenders without BIM requirements, 31 % in tenders with BIM requirements, 18 % had bid for tenders without BIM requirements, 29 % for tenders with BIM requirements, and 6 % had no tendering experience despite having knowledge of the country's public sector.

Table 1
Examples of the case studies proposed to BIM experts.

Case study	Type	Description	Estimated contract value (€)	Category	Duration (months)
Construction project for a cycle and pedestrian path between two population centers	Civil infrastructure	The new cycle and pedestrian path will be 6.70 km long and will have two-way traffic. The path will run parallel to the route of the road that connects both population centers.	83,407.10	1	8
Refurbishment project for a residential building	Buildings	The building has a built surface area of 8000 m^2 and 59 dwellings. The refurbishment project will include the reinforcement of the structural system, the interior redistribution of the dwellings, and the interior urbanization of the block.	180,000.00	2	6
Construction project for an interconnection highway	Civil infrastructure	New road has a length of 3.25 km. Road section will consist of 2 carriageways, each 7 m wide, 2.5 m wide outer shoulders, 1 m wide inner shoulders, and a 1–5 m wide median.	614,314.71	3	10
Works management for the construction of a transformer substation	Mechanical and electrical facilities	The power to be installed in the new electrical substation will be 60 MVA, distributed in two identical transformers of 30 MVA each.	778,169.13	3	23
Works contract for the refurbishment and extension of a nursing home for the elderly	Buildings	The building has three floors and is located on a site with a surface area of 1561.56 m^2. The works will include the interior redistribution of the floors to add a kitchen, a dining room, an office, an adapted toilet and bathroom, and 15 new bedrooms.	1,511,300.00	4	12
Works contract for the construction of a nursery and primary school	Buildings	The new building will have a built surface area of 3784.85 m^2 with 25 classrooms, 17 toilets, 1 gymnasium, 5 offices and 1 staff room, distributed over 2 floors. The works will include the interior urbanization of the site.	5,887,501.56	6	18

3.3. Semi-structured interviews

The second phase of the study involved questionnaire-supported interviews with experts. Each participant received a case study according to their professional profile and was asked to complete a total of 30 questions. The questionnaire consisted of two main sections: one addressing the implementation of BIM methodology in Spanish public sector contracts, and another focused on BIM requirements that should be included in tenders. These survey questions were formulated based on the analysis of the Spanish public procurement sector from 2018 to 2022.

4. Results

4.1. BIM evaluation in tender documents

In the first section of the survey, participants answered 5 questions to assess the ways in which BIM methodology is included in Spanish public sector contracts. The experts evaluated whether the current state of maturity in the Spanish market would support the incorporation of BIM into all contracts through technical solvency (Q01 and Q02). Slightly over half (53 %) disagreed, citing reasons such as the lack of training or knowledge in BIM (29 %), resource and collaboration challenges (6 %), implementation delays (6 %), or the absence of standards and operational procedures in companies and administrations (3 %). Arguments in favor included the existence of tenders with BIM requirements in the country's public sector (12 %), or the large number of professionals trained in or using the methodology (9 %). Additionally, among those advocating for technical solvency (I1) as a means of introducing BIM, 9 % believed it depends on the willingness of administrations and companies, while 6 % considered it reliant on the nature of the contract.

BIM requirements for technical solvency (I1) in the Spanish market typically involve two criteria: the inclusion of professionals with BIM training and the company's prior involvement in BIM projects. Among the respondents, 35 % considered these requirements adequate (Q03), while 10 % preferred bidders to possess accredited certifications, such as ISO 19650. 8 % suggested requiring companies to have the necessary infrastructure (ICT), tools, procedures and operational methods for BIM project development. Furthermore, 5 % recommended that participating agents hold certificates demonstrating their successful use of the BIM methodology in previous projects or works.

Regarding the documentation required in the administrative clauses as evidence of the BIM requirements for technical solvency (Q04), 55 % of the interviewed professionals considered that it should include certificates of satisfactory execution, curricula vitae, lists of BIM projects in which agents have been involved, or a responsible statement of participation in these projects.

12 % suggested accredited certifications, 10 % BIM training certificates, 7 % self-evaluation tests or personal interviews, and 10 % a list of company BIM software licenses or BIM projects development procedures.

The participants employed a Likert scale to assess the importance of various BIM-related award criteria (I2) that are typically included in public sector contracts (Q05). The criteria that received the highest average scores were the availability of a Common Data Environment (CDE), the alignment of the BIM methodology with the specific requirements of the contract, and the strategy for implementing BIM. Each of these was rated as 'very important' by 55.88 %. The criteria considered less significant included the organization's ISO 19650 certification, the BIM software mapping, and the incorporation of additional BIM uses.

4.2. BIM requirements for tenders

The second section of the survey analyzes those BIM requirements that are most frequently included in Spanish public sector tenders. This part of the survey consists of a total of 25 questions, which cover the following topics: BIM uses, deliverables, deliverable formats, information levels, common data environment requirements, classification systems, information management standards, model quality control checks, BIM roles or functions, and BIM experience/training of the roles.

4.2.1. BIM uses

The BIM uses most valued by the participants (Q06) were existing conditions modeling and 3D coordination and collision management, both with 88.24 %. These were followed by budget estimation (85.29 %), quantity take-offs (82.35 %), 2D documentation generation (79.41 %), 3D design and visualization (73.53 %), and executed work modeling (64.71 %). Less important uses included digital manufacturing (2.94 %), cost−benefit analysis (CBA) (2.94 %) and emergency plans (14.71 %). The complete list of BIM uses is included in Appendix A (Fig. 5).

Other BIM uses cited by professionals in open response (Q07) comprised the investigation of alternatives, signage and corporate image, examination of unique finishes and carpentry, piping and instrumentation (P&ID) diagrams linked to the model, and the connection of equipment to an operations and maintenance system.

4.2.2. BIM deliverables

The deliverables rated as most relevant (Q08) included quantity take-offs (85.29 %), the BIM execution plan and budget (both 82.35 %), plans (79.41 %), construction project models (67.65 %) and the BIM model manual (67.65 %). The lowest-scoring deliverables were construction monitoring models (8.82 %), starting construction works models (11.76 %), simulations (20.59 %) and health and safety models (26.47 %). The complete list of BIM deliverables is included in Appendix A (Fig. 6). Among the deliverables suggested in open response (Q09) were existing conditions models, energy/lighting simulations, design documents in the shared and published information states, IFC models enriched with the application results of the described uses, the Master Information Delivery

Plan (MIDP) or the BIM manager's report approving the correct BIM development.

Over half of respondents (52.94 %) believe that native formats of BIM deliverables should be required in tenders (Q10). The main reasons (Q11) for this included facilitating model changes when needed by the administration, ensuring continuity throughout the lifecycle of models, preventing data loss in open workflows, and avoiding the limitations associated with exchange data in civil engineering projects. Opposing views highlighted the hindrance of cooperation with proprietary formats and the technological constraint of native format requirements. These concerns can hinder administrations in upholding the principle of technological neutrality and free competition. Some participants added that the inclusion of native formats in tenders can be positively valued but must not be imposed.

In relation to BIM models (Q12), the majority (84.31 %) of respondents considered that the IFC schema should be required. Among them, 47.06 % indicated IFC4 and 37.25 % IFC2x3. For plans (Q13), 58.18 % of participants would demand the PDF format, while 32.73 % would opt for the DXF format. Regarding quantity take-offs and budgets (Q14), 74.42 % considered the BC3 format, a standard commonly used in Spain, and 23.26 % indicated the CSV format. In the context of point clouds (Q15), 52.27 % required the E57 format, 25 % the CSV format, and 22.73 % mentioned other formats, including LAS, PLY, XYZ, or TXT. In the case of model data/property sets (Q16), 46.55 % would require CSV/TXT formats, 36.21 % would opt for COBie, and 17.24 % mentioned other options, such as IFC, eCOB, ODBC or spreadsheets.

4.2.3. *Levels of information*

The majority of experts (94.12 %) consider it necessary to define the level of information required in tenders (Q17). ISO 19650-1 introduced the concept of Level of Information Need (LOIN), a framework to define the quality, quantity and granularity of information [31]. However, to date, the Spanish public procurement sector has focused on Level of Development (LOD), which identifies the specific minimum content requirements and associated authorized uses for each model element [32]. For this reason, participants who answered affirmatively to the previous question were asked to specify both the maximum (Q18) and minimum (Q19) LOD needed for the proposed case study. 30 % of the sample chose LOD 300 as the maximum level, while 27 % selected LOD 350. For the minimum level, LOD 300 was chosen by 31 % of the respondents, followed by LOD 200 (29 %) and LOD 100 (14 %). It should be noted that some of the participants would prefer a detailed description of the asset's geometric requirements and attributes over defining a LOD.

Regarding the levels of graphic information (Q20), 38.24 % would define them by technical discipline (Architecture, Structure, Installations, etc.), 35.29 % by phases and elements, 5.88 % at a general level, and 20.59 % would suggest other forms than those mentioned.

For the level of non-graphic information (Q21), 44.12 % would define it by technical discipline, 29.41 % by phases and elements, 8.82 % at a general level, and 17.65 % would establish it using different methods from those mentioned above.

4.2.4. *Common data environment*

On a Likert scale, the experts rated the degree of importance they would attach to each of the Common Data Environment (CDE) requirements (Q22). Data version control and exchange of information received the highest average rating of 'very important' (70.59 % each). These were followed by the flow of information states and storage of information (both 64.71 %) and ensuring interoperability through the use of open formats (58.82 %). Compliance with the Organic Law on Data Protection, the potential for integration, and the embedded viewer for monitoring meetings were rated as less important (Fig. 2).

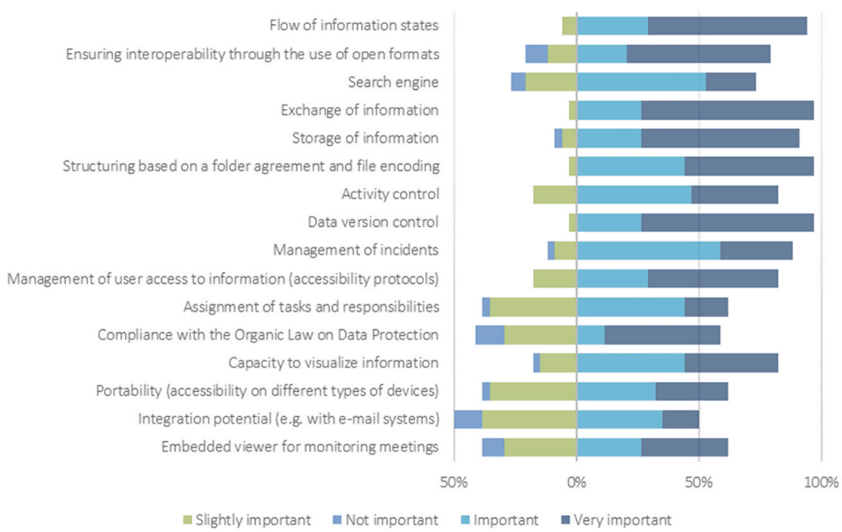

Fig. 2. Importance attributed to Common Data Environment requirements (Q22).

4.2.5. *Classification systems and standards in information management*

79.41 % of professionals consider it necessary to require some system for classifying elements in tenders (Q23). The inclusion of the contracting authority's own system in the contract is the most highly valued option by all participants (25 %) (Q24). This is followed by the GuBIMclass classification system (22.73 %), Omniclass (20.45 %), SCFClass (11.36 %), and Uniclass (6.82 %).

On the other hand, 62.16 % of respondents believe that tenders should require compliance with a specific standard in information management (Q25). Among the list of proposed standards (Q26), ISO 19650 received the highest rating (61.76 %). 11.76 % would opt for one of the contracting authority's own standards, and 23.53 % of the sample provided different answers, such as using a standard proposed by the contractor or the simultaneous employment of ISO 19650 and EN 17412–1:2021.

4.2.6. *Quality control*

Quality control of models was assessed using a Likert scale. The professionals indicated the level of importance they assigned to various verifications commonly included in Spanish public tenders (Q27). The highest ratings in the 'very important' category were for the control of model location (coordinates) and geometric checks (76.47 % and 73.53 %, respectively). Nomenclature and data coding verification received 61.76 %, while coordination between models stood at 50.00 %. Regulatory checks or checks on non-graphic information were considered less relevant (Fig. 3).

4.2.7. *BIM roles*

BIM roles or functions refer to the project team members assigned BIM responsibilities. Survey respondents evaluated which roles should be required for a tender team (Q28). 28.71 % of the sample would incorporate a BIM Modeler, 20.79 % a BIM Coordinator, 17.82 % a BIM Manager and 11.88 % a BIM Project Manager. The least chosen role was the Information Manager, at 2.97 %.

The majority of respondents consider that the minimum educational level required for almost all BIM roles (Q29) is Higher Technician (European Qualifications Framework, EQF, level 5). The only exception is the role of BIM Project Manager, for which 47.06 % of the sample indicated a Master's degree (EQF level 7) as the minimum qualification for its performance.

According to 17.5 % of respondents, the minimum experience required for BIM roles or functions (Q30) should be assessed solely based on the number of contracts on which they have been involved, 15 % based on years of experience performing similar work, and 47.5 % selected both options. The remaining 20 % provided other answers, such as accredited training and experience, or the quality of deliverables.

5. Proposal to include BIM in public procurement

As a result of the analysis of the information gathered, this study presents a framework for the adoption of BIM in Spanish public procurement. Fig. 4 illustrates the proposed workflow for the pre-procurement phase, which identifies the different instruments for incorporating the methodology into public contracts and helps contracting authorities to select the most suitable approach.

Before proposing a tender, the contracting authority should conduct a needs analysis to identify the contract's requirements and demands. The analysis will help to establish the contract's maturity level, its subject matter and key characteristics. This will enable the categorization of the tender and the determination of the essential information requirements for a proper definition of the service or work.

The proposed maturity assessment is aligned with the BIM Maturity Matrix, formulated by Bilal Succar [33]. It serves as a tool to evaluate the level of knowledge and implementation of the methodology within an organization. In this context, maturity encompasses both the public client's readiness (i.e., the contracting authority) and the AECO sector's capability in the region where the tender is to be carried out (i.e., the potential companies that will offer their services). Aligning the introduction of BIM with the existing sector maturity will enable the successful bidder to deliver the service or work in accordance with the contract's specified criteria. Likewise, public administrations with low levels of maturity requiring extensive implementation of the methodology in their contracts often

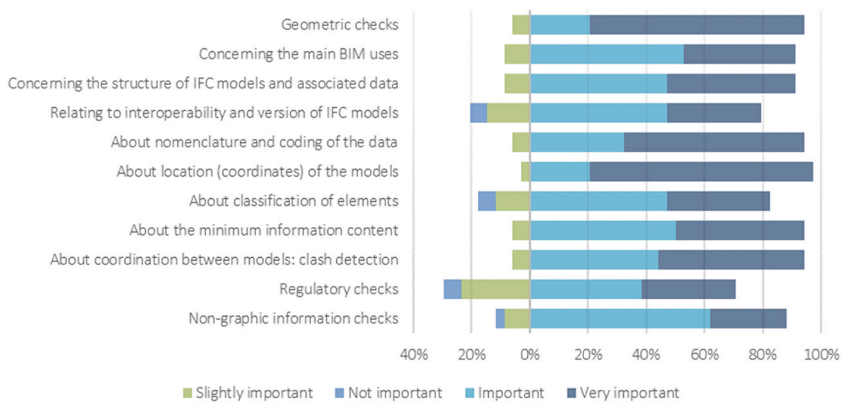

Fig. 3. Degree of importance attached by respondents to quality control checks of the models (Q27).

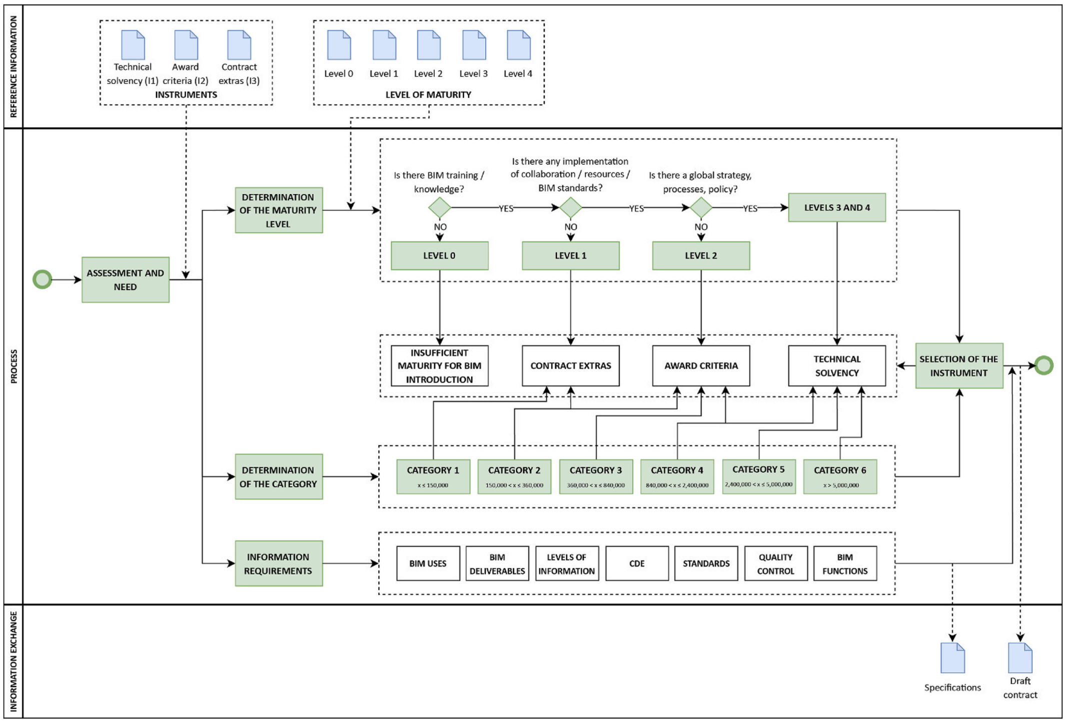

Fig. 4. Proposed framework for the inclusion of BIM in Spanish public procurement.

struggle to effectively manage all the information generated.

A level 0 would indicate that the administration or sector lacks the necessary BIM maturity to implement the methodology in the contract. Level 1 would signify a certain degree of BIM knowledge or training; however, imposing high demands on the methodology's use might not be feasible. In such cases, incorporation through contract extras (I3) would be the most suitable approach. Level 2 would denote a degree of control and management in BIM usage; collaborative working and/or standards are implemented, making it possible to require their introduction as part of the award criteria (I2). Finally, maturity levels 3 and 4 would reflect the full integration and optimization of the methodology, along with the existence of global strategies and policies. In such scenarios, its adoption could be required as part of the technical solvency (I3) of the contracts.

The category consists of six levels, arranged in ascending order of economic value. Including BIM as contract extras (I3) would apply to categories 1 and 2. Requiring the methodology as award criteria (I2) is recommended for categories 2, 3 and 4. Finally, stipulating the use of BIM as part of the technical solvency (I1) is considered appropriate for high-value contracts, namely categories 4, 5 and 6.

Once the instrument for BIM implementation has been chosen, the public organization must define the necessary information requirements according to the subject of the contract. The list of requirements included in the results section of this document serves as a guide for this purpose.

6. Discussion and conclusions

A mixed methods approach, involving questionnaires and semi-structured interviews with experts possessing knowledge and experience in public procurement, was used to evaluate the contractual aspects of BIM adoption in the Spanish public sector. This research makes a significant contribution to the existing knowledge. Participants highlighted the lack of market maturity as an obstacle to implementing BIM methodology throughout the asset lifecycle. Selecting the right instrument for BIM inclusion, developing information requirements at the appropriate level of detail and ensuring compliance can sometimes be complex for public administrations.

Another contribution of this study is the characterization of the instruments for the inclusion of the methodology into public procurement. A framework has been developed to guide public administrations in the implementation of BIM. Before proposing a tender, the contracting authority must conduct a needs assessment to determine the requirements and demands of the contract. This should encompass an analysis of their own BIM maturity level and that of the companies in the sector, as well as the subject matter and characteristics of the contract. High demands for incorporating the methodology, without considering the above issues, may result in the tender being declared invalid or the successful bidder failing to meet the criteria and deadlines specified in the contract, which may affect the quality of the results.

The indications contained in the proposal made are presented as a baseline, and the contracting authority has the final decision on how to incorporate the methodology. The proposal has been developed in accordance with the formal procurement procedure in Spain. It is based on two key elements: the maturity, determined through a series of questions, and the category of the tender, based on its economic value. These aspects are aligned with the existing instruments for the introduction of BIM in Spanish public tenders: technical solvency, award criteria and contract extras.

In addition, based on the proposed case study, the participants highlighted what they considered to be the most relevant information requirements in a public tender. These are proposed as a knowledge base for the preparation of the EIR as part of the contract documentation.

The limitations in this study are those inherent in any research in a specific region with a certain number of participants. The methodology applied, expert interviews, aimed to understand the level of knowledge among AECO sector professionals about the methods to introduce BIM in the Spanish procurement process, in order to explore a framework approach for its implementation. Although the participants were selected on the basis of their expertise in the use of BIM and public procurement, the authors admit that the results may not be applicable to all contexts. It can serve as a guide for other countries, but its content cannot be extrapolated in its entirety, as it is a study on the adoption of BIM in Spain. Furthermore, this study represents an early stage in the use of BIM in the public sector in the country and the authors recognize that BIM practices and contracts evolve over time. Future work considers checking and managing of BIM data models from the country's public procurement, using the Information Delivery Specification (IDS). IDS is a standard in development from buildingSMART for defining information requirements in a way that is easily read by humans and interpreted by computers. The objective is to (1) assess the quality of information in BIM models of public buildings and infrastructure in order to improve and streamline their management through various life cycle phases, and (2) establish a set of information requirements that could serve as a basis for the country's public administrations to develop their own. The information exchange requirements for each BIM use case applied to the different phases of the life cycle of an asset's in public procurement could be also an interesting topic to address. Areas such as sustainability and energy analysis, quantity estimation, planning, regulation code validation or space management could be discussed.

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Data availability statement

The authors declare that no data associated with the study has been deposited into a publicly available repository. Data will be made available on request.

CRediT authorship contribution statement

Ana Pérez-García: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Norena Martín-Dorta:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **José Ángel Aranda:** Writing – review & editing, Visualization, Supervision, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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