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BPMN 2.0 TO REDEFINE ITALIAN DESIGN-BID PROCUREMENT IN AN INNOVATIVE MODEL-BASED, OPEN-SOURCE APPROACH

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Abstract

An inherent complexity characterizes the construction industry with struggling information management, worsened by low digitalization, lack of interoperability, and formalized processes. The digital transition of process management is crucial to define data-driven tools, enabling consistent information creation, sharing, and exchanging. The paper focuses on the Italian Design-Bid procurement, exploiting BPMN 2.0 to propose its redefinition in a model-based, open-source approach. It aims to provide a breakthrough, unlocking the still under-exploited potential of BIM and digital tools. Information exchanges can be identified, and also bidding models information requirements. The innovations introduced are discussed, highlighting how efficiency, transparency, and consistency can improve.

Background and motivation

It is a matter of fact that Building Information Modelling (BIM) and digital tools boosted construction industry productivity. Nonetheless, low digitalization and efficiency are still important issues, mainly due to the severe fragmentation, lack of interoperability, and struggling collaboration between stakeholders throughout the lifecycle (Mc Kinsey Global Institute, 2017; Orae et al., 2017). Indeed, an intrinsic complexity characterizes the construction industry and its projects due to the presence of multiple actors from different disciplines, dealing with diverse languages and tools. Furthermore, approaches are still paper-based, and behaviors are competitive rather than collaborative, preventing the correct BIM adoption (Borrmann et al., 2015; Sacks et al., 2018). A key gap lies in the lack of processes agreed representation, opposite to other industries such as manufacturing where data and process models are developed contemporarily starting from a prototype, fully exploiting their potential (Srećković et al., 2022; Corneli et al., 2021; Succar et al., 2020). An efficient Information Management (IM) strategy is required and recognized as a game changer in a more digitalized, productive, and efficient construction industry (Mc Kinsey Global Institute, 2017; Sacks et al., 2018; Borrmann et al., 2015; Rezgui et al. 2011). At this aim, the reference standard is ISO 19650-1:2018 whose cardinal principle lies in the correct and clear information structuring. Three growing stages of BIM maturity are defined. Until now, the industry dealt with “BIM stage 2” exploiting authoring files integrated into a federated model through a CDE (Common Data Environment), from which to extrapolate 2D plans and specifications as .pdf files (Borrmann et al., 2015). Now the transition towards "BIM stage 3" must be fulfilled to unlock the full potential of digitalization. It deals with seamlessly integrated digital information containers, stored on cloud services, and shared throughout the building lifecycle. The "BIM stage 3" provides a structured, easily updatable, and accessible single source of knowledge. It can be exploited to manage consistent information exchanges among stakeholders, supporting efficient and effective decisions, also through model-based and automated approaches. At this aim, a relevant part of the BIM approach should deal with process modelling, focusing on processes needed to generate, modify, and share information throughout the building lifecycle (Borrmann et al., 2015; Comai et al., 2022). Thus, a core part concerns the digital transition of process management as BIM deals not only with introducing new digital technologies and designing tools. BIM also involves the reorganization of project management processes with a focus on IM (Sacks et al., 2018; Borrmann et al., 2021; Srećković et al., 2022) and on consistent Information Requirements (IRs) definition, tailored to the managed phase and its scope (Rezgui et al., 2011; Armajo et al. 2022). Indeed, ISO 19650-1:2018 states that the level of information needed (LOIN) must be the minimum sufficient to manage a task, avoiding redundancy or noise that prevent effective decisions.

The criticalities individuated, typical of the construction industry, are particularly significant in public procurement (EU Commission, 2017; EU Commission, 2019). Even if it represents 14% of GDP, it is still poorly digitalized, highly fragmented, and characterized by inefficiency. The main reason lies in still paper-based approaches that complicate IM and tender evaluation, resulting in long processing times and low decision speed (EU Commission 2019; Agenzia per la coesione territoriale, 2018; Grilo et al., 2011). Thus, European directives (2014/24/EU Directive) highly promote strategies based on digital and data-based approaches to enhance public procurement productivity. It was demonstrated that improving it of even of 1% could save 20 billion euros per year (EU commission, 2017). The Italian public procurement particularly suffers from these issues with a "decision speed" (i.e. average time between

the deadline for receipt of bids and the awarding date) among the lowest in Europe. This demonstrates the urgency of streamlining tender and evaluation processes, for which fully digital, automated, and user-friendly systems are core. Current procurement and tender processes are mainly held via electronic platforms, although still designed to provide and deliver digitally signed .pdf documents (Consip, 2017; Anac, 2021). On the contrary, they should rely on data suitable to feed digital models as a unique knowledge repository, informing decisions throughout the lifecycle. Checking the bid documentation is struggling as mainly based on paper-based declarations and reports with difficulties in tracing information and verifying consistency. This results in the under-exploitation of information models' potential, preventing their content verification against defined IRs, and often shifting away from the original intent due to their incorrect interpretation and formalisation (Locatelli M. et al., 2022).

The research aims to redefine and revolutionize current public procurement processes towards a model-based and "BIM stage 3" approach. The main objective consisted in enabling complete digitalization, transparency, and shortening of the tendering phase, exploiting information management and modelling, and digitalization potentials. It focused on the case study of Italian Design-Bid (DB) procurement with the Most Economically Advantageous Tender (MEAT) criterion, suitable to develop and assess the proposed redefined approach. DB procurements are recognized as optimal for the implementation of collaborative and information modelling approaches (Pellegrini et al., 2021; Sacks et al., 2018; Di Giuda et al., 2015). MEAT criterion is the most applied as strongly promoted by EU directives and national regulations, even though it presents diverse criticalities (Di Giuda et al., 2015). It aims to identify the most convenient bid, crossing quality and price based on the lifecycle performance of a project. Often, its correct application is difficult due to the variety and complexity of parameters to be evaluated by a Judging Commission of experts. This results in high subjectivity in the judgment and awarding of bids; rather than avoiding it in compliance with the following three principles: equal treatment, transparency, and non-discrimination (EU Commission, 2019). In addition, the chosen bid does not always turn out to be exactly the best in terms of performance, quality, costs and sustainability. It is hard for the Commission to keep track of all the multiple criteria to be met, defined by both Public Client and regulations. This is due to the poor exploitation of digital technologies and information models, with processes still highly paper-based or at least “paper- thought”, and information that has to be sourced through a long series of documents and reports. Indeed, BIM models use and delivery during the bidding phase is prevented by regulatory barriers (L.D. 50/2016 and the related M.D. 560/2017) even though it is required through tailored rewarding criteria, and it will be mandatory for all procurements starting from 2025. The procedures of evaluation and entrustment result furtherly slowed by long processing times (Agenzia per la coesione territoriale, 2018). A digital, semi-automated method would be crucial for the easy project performance control and evaluation (EU Commission, 2017). It must also be designed from an open-source perspective, as required by the EU Commission and national regulations to improve the interoperability and transparency.

Overcoming the current legal barriers by introducing BIM during the tendering phase is not enough. A shift towards model-based approaches with formalised and linked processes and information is needed. The work illustrated exploits the Business Process Model and Notation (BPMN 2.0), the international open standard defined by (Object Management Group) to formalize the current DB procurement with MEAT criterion, according to regulations. BPMN 2.0 enables the visual description of complex business processes through diagrams built from defined graphic elements. It simplifies the understanding of business processes and tasks for users of diverse backgrounds and expertise, improving interoperability. In addition, it provides clear and seamless IM and machine-readable processes exploitable through a web-based platform and a BIM Engine to invoke user actions and micro-services or algorithms, and also tasks automation. Recently, it started to be diffused in the construction industry to fill the gap of process modelling in a graphical but machine-readable format (i.e. xml), enabling the storage of data models with their generating processes, and task automation (Von Rosing et al., 2015). Its diffusion is also due to ISO 29481-1:2017 standard, recommending it to represent process maps and provide a comprehensive overview of a business process with its IRs. There were numerous examples of BPMN 2.0 application in the construction industry to represent model development, collaboration, and data exchange processes. (Gardini et al., 2020) used it to model the inspection of execution processes during construction; (Corneli et al., 2021) provided a framework for the digitalization of construction site processes through blockchain and smart contracts. (Comai et al., 2022) exploited BPMN 2.0 to manage information exchanges in construction inspections and quality checks during the supply and installation of an External Thermal Insulation Composite System. Finally, (Armijoet al., 2022) presented an interesting use case, exploiting BPMN 2.0 to define OpenBIM workflows of the buildings' renovation process and IRs according to the diverse stakeholders involved.

Methodology

The paper illustrates the first step of a wiser research aimed at developing a Proof-of-Concept for the design phase of a building's lifecycle. It aims to show how procedures can be developed and automated through an open-source, web-based, collaborative platform (MIUR, PRIN 2017). The main goal is to define the IRs, maintaining their consistency through the design phase and the whole lifecycle, avoiding shifting away from the

original intent. Crucial, especially during technical bid evaluation in competitive tenders. The first step towards such a goal concerns procedures mapping and modelling to provide their formalization and redefinition in a fully digitalized, open-source way. Thus, the structured definition of IRs can be provided thanks to the clear visualization of the process and its tasks. This provides a more coherent and consistent IM, improved interoperability (Srećković et al., 2022, Armijoet al., 2022), and automated or semi-automated tasks, ensuring information models consistency along with better decisions and control over design choices impacts.

The approach adopted consisted of the following steps:

1. Analysis of the regulatory framework, guidelines, and standard tender notices regulating current Italian DB procurements, with a focus on electronic ones;
2. BPMN 2.0 process modelling of current DB procurement with MEAT through the open-source Camunda modeler;
3. BPMN 2.0 process redefining in an innovative, open-source, model-based approach with automatable tasks.

Regulatory framework analysis

The first step concerned the examination of the Italian Legislative Decree (L.D. 50/2016), namely "The contract code" and its subsequent updates. It transposes the 2014/24/EU Directive, requiring BIM adoption as mandatory for every public works from 2025, adoption of electronic tools and digital procedures, and application of the MEAT criterion for all procurements over 40.000 €. In particular, the recent Ministerial Decree (M.D.) 312/2021 establishes the modalities and timing for the gradual introduction of electronic modelling methods and tools for construction and infrastructure, introducing awarding criteria accordingly. Furthermore, the M.D. 148/2021 that regulates how to digitalize public contract procedures pursuant to Article 44 of L.D. 50/2016, was analysed along with the guidelines provided by ANAC (i.e. National Anti-Corruption Authority) concerning the model tender notices drafting for conducting DB procurements. Other documents consulted were the tender notices already published and/or conducted with a request for BIM, as well as the Consip S.p.A. guidelines for using the MePA electronic platform (Consip, 2017), currently the most widely used by Italian public administrations for purchasing goods, services and works through MEAT criterion. The analysis pointed out that all the procedures above 40,000 € must be conducted via an electronic platform, including DB.

This step provided a clear picture of the current DB procurement process and enabled its mapping. The tasks and actors involved were individuated, along with tender documents, data created or exchanged, how and when. It also helped to point out the criticalities of the current paper-based approach, preventing the automated or semi-automated checking of bidding documents. Indeed, they mainly consist of paper-based declarations and reports, digitally signed, struggling with adequate information consistency checking against Public Client and regulatory requirements (i.e. IRs).

BPMN 2.0 process modelling of current DB

The second step dealt with the formalization of the current DB procurement with MEAT award criterion, based on a validated final project. It was modeled according to the current procedures carried out through MePA platform (Consip, 2017), referring to the regulations and guidelines identified in the analysis of the regulatory framework. The process was formalized in a machine-readable, graphical way through BPMN 2.0 (Figure 1). This provided a comprehensive understanding of the process and needed tasks, in addition to the identification of which information should be provided and exchanged at each step, by whom, and in which format. Furthermore, it was possible to identify which tasks could be accomplished by users, micro-services and algorithms. This is crucial, especially in model-based approaches, providing the understanding of how to feed the model with useful information for decisions connected to each step of the process (Gardini et al., 2020, Corneli et al., 2021) and how to automatize or semi-automatize tasks

BPMN 2.0 process redefinition in an innovative, model-based, open-source approach

Moving from the precedent assumptions, model-based processes in the construction industry can be defined. This unlock the ability to develop tools aimed at boosting interoperability and digitalization, automatizing some tasks, and ensuring the model consistency against the client's and regulatory IRs (Armijoet al., 2022, Corneli et al., 2021). Thus, the third step concerned the redefinition of the current DB procurement with MEAT in an open-source, innovative, model-based approach (Figure 2). The main objective concerned the streamline of the tendering and evaluation processes, the promotion of the bidding process digitalization, some tasks automation, and the identification of information needed at each step, enabling the clear definition of IRs. This is disruptive as not only allows to optimize the process in terms of both time and costs, but it can provide the long-mentioned and awaited digital breakthrough in the industry.

Results and discussion

Observing the BPMN formalization of the current DB process (Figure 1), there are four lanes representing the actors involved. One represents the electronic platform through which information exchange takes place (Consip, 2017). The two lanes above represent the Public Client and the Judging Commission, while the lane below that of the Bidders. The three actors exchange information with the platform during the whole process, instantiated with the validation of the final project, placed among the tender documents as a .pdf file. Tasks automation is absent except with regard to the checking of the administrative tender documentation completeness. The process is

digitalized, not formally and uniquely, with bids still submitted and evaluated through documents, even though electronically signed. The full potential of digitalization is not exploited as BIM models cannot be submitted and used to evaluate bids, preventing the automation or semi-automation of the projects' completeness checking against the IRs, as well as the awarding process. This latter task is still totally entrusted to the Judging Commission of experts with a judgment inexorably based on their own subjective experience, even if the tender notice defines the criteria and the awarding quantitative scores (Di Giuda et al., 2015). This slows down evaluation and entrustment of bids, due to the struggling documentation examination and the need for several sessions of the Commission with associated long processing times due to the availability of the experts. It also leads to a significant consistency problem: the project delivered and awarded during the bidding process often does not correspond to what will be executed and delivered after the contract is signed, due to the difficulties and lack of control.

To overcome the gaps identified and take full advantage of digitalization and BIM, the current telematic procedure is re-engineered into a model-based perspective. Figure 2 shows the redefined process, while Table 1 illustrates the multiple innovations introduced with related impacts, following illustrated.

The redefined process still foresees four lanes related to the actors afore described, but now the second lane from the top represents the interface with the web platform (i.e. "BIM server"). The whole process is based on open formats data (e.g. .csv, .pdf, .xml, and so forth) as required by regulations to enhance interoperability and data accessibility. Bids are submitted through BIM models exported in IFC (Industry Foundation Class), the open standard defined by ISO 16739, drafted according to the Client IRs, and structured according to the final validated project available through the web platform, still instantiating the tendering procedure. This is the most disruptive requirement, as according to current regulations bids must be submitted through digitally signed documents, preventing the submission of information models. Exchanges with the platform increased, and the process streamlined. Such interactions with the web platform enable to store projects and data in Collections (i.e. non-typed, highly queryable data structures) accessible through predefined and customized queries. The platform also stores processes mapped in a machine-readable format (i.e. .xml), exploitable through a BPMN engine that can recall connected workflows or sub-processes, or invoke needed micro-services (MIUR, PRIN 2017). This unlocks the possibility to automate or semi-automate some tasks such as model-checking, existence of anomalous bids and score calculation (highlighted in blue in Figure 2). When the platform is asked to accomplish some of this tasks, the related BPMN sub-process is activated by the BPMN engine and in turn calls up: (i) the related sub-process and tasks; (ii) the micro-services, algorithms, and user actions required; (iii) the queries defined to extract needed data useful accomplish the managed task. Disruptive innovations can be introduced. Firstly, it the automated model-content checking ensures greater consistency with IRs (Di Giuda et. Al, 2015). Secondly, the awarding sub-process through MEAT criterion could be semi-automated, taking in input data directly from the bid models and exploiting algorithms to calculate quantitative scores. Tailored queries should be defined for each evaluated criterion and sub-criterion, based on awarding rules and criteria weight. The qualitative scores will be still evaluated by the Judging Commission whose role shifts to be more contained and notarized role.

Table 1: Process innovations and related expected impacts

Process innovation	Expected impact
Submission of bidding information models	Highly queryable data, better compliance checking
	Truthful building prototype useful to compare diverse scenarios and set the basis for DTs
Formalized, machine readable processes stored with data in a web-based platform	Tasks automation or semi-automation (model checking; anomalous bids, bids evaluation)
	Ability to invoke micro-services and algorithms or user actions
	Queries customized based on LOIN and the managed task
Open formats (IFC, .xml, .pdf, .csv..)	Improved interoperability, data accessibility and transparency
	Reduced software cost
Semi-automated criteria evaluation though MEAT	Improved objectiveness and transparency
	Process streamline
	Less error prone
Analytic dashboards	Systematic visual comparison of bids project performance
Clearly defined information exchanges and related IRs	Project quality, bids consistency, compliance with Public Client and regulatory requirements
	Definition of information standards and protocols
Judging commission role	Less subjectivity
	Reduced sessions, tendering duration and costs

A "BIM stage 3" approach can be achieved, with fully accessible and queryable data and information according to the activity to be fulfilled. At this aim, an accurate IM approach is core to provide a clear definition of IRs according to the process managed. A key document is the "Information specification" which in the current procedure is desirable but not mandatory, with no guidelines to drive the definition of the IRs. In the redefined process it becomes mandatory and must contain the IRs mapped in IFC accordingly to the required LOIN and task to manage. Furthermore, the "Guideline for bid compilation" introduced among tender documents will

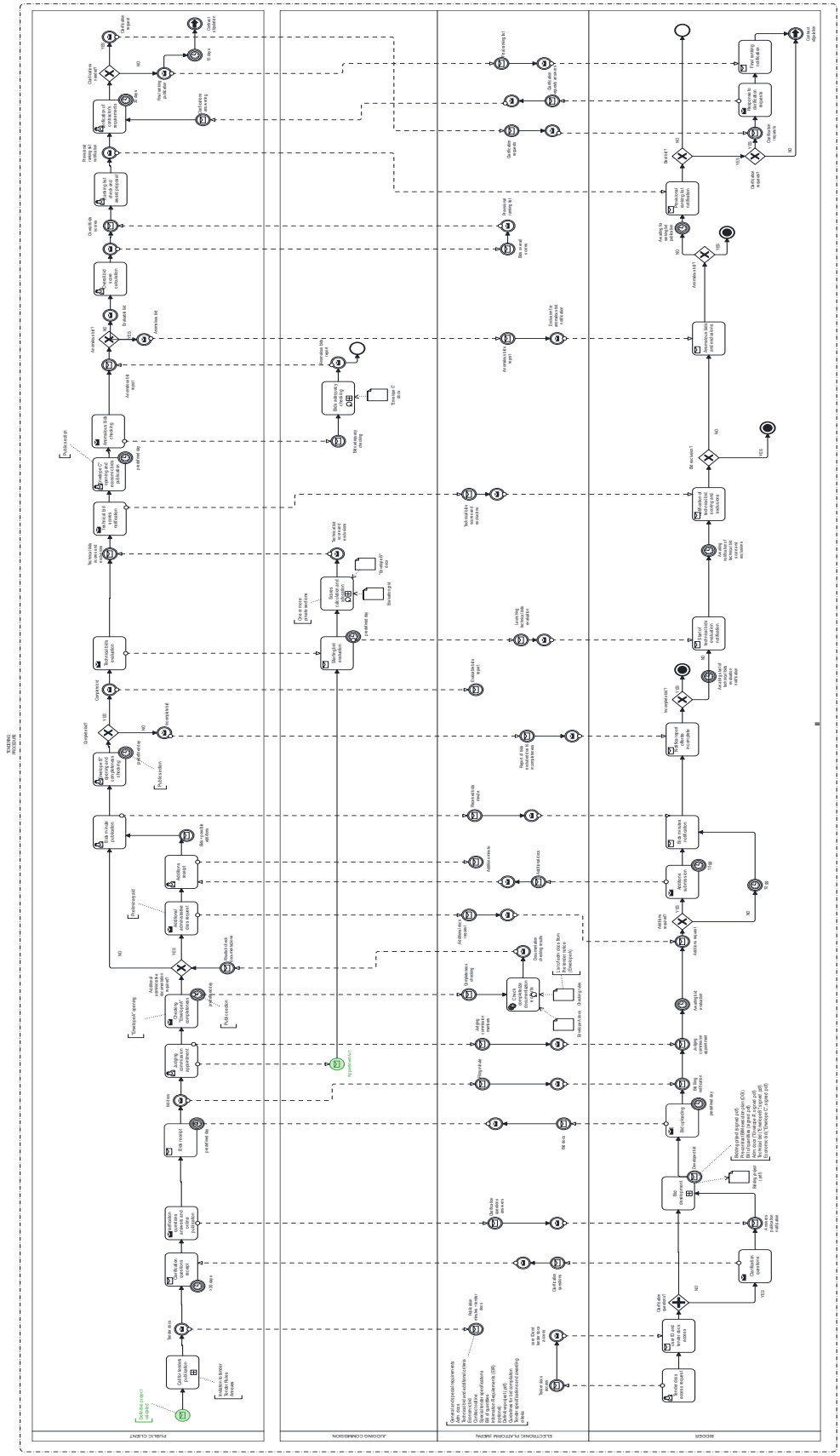

Figure 1: BPMN of current Design-Bid procedure with MEAT criteria via electronic platform

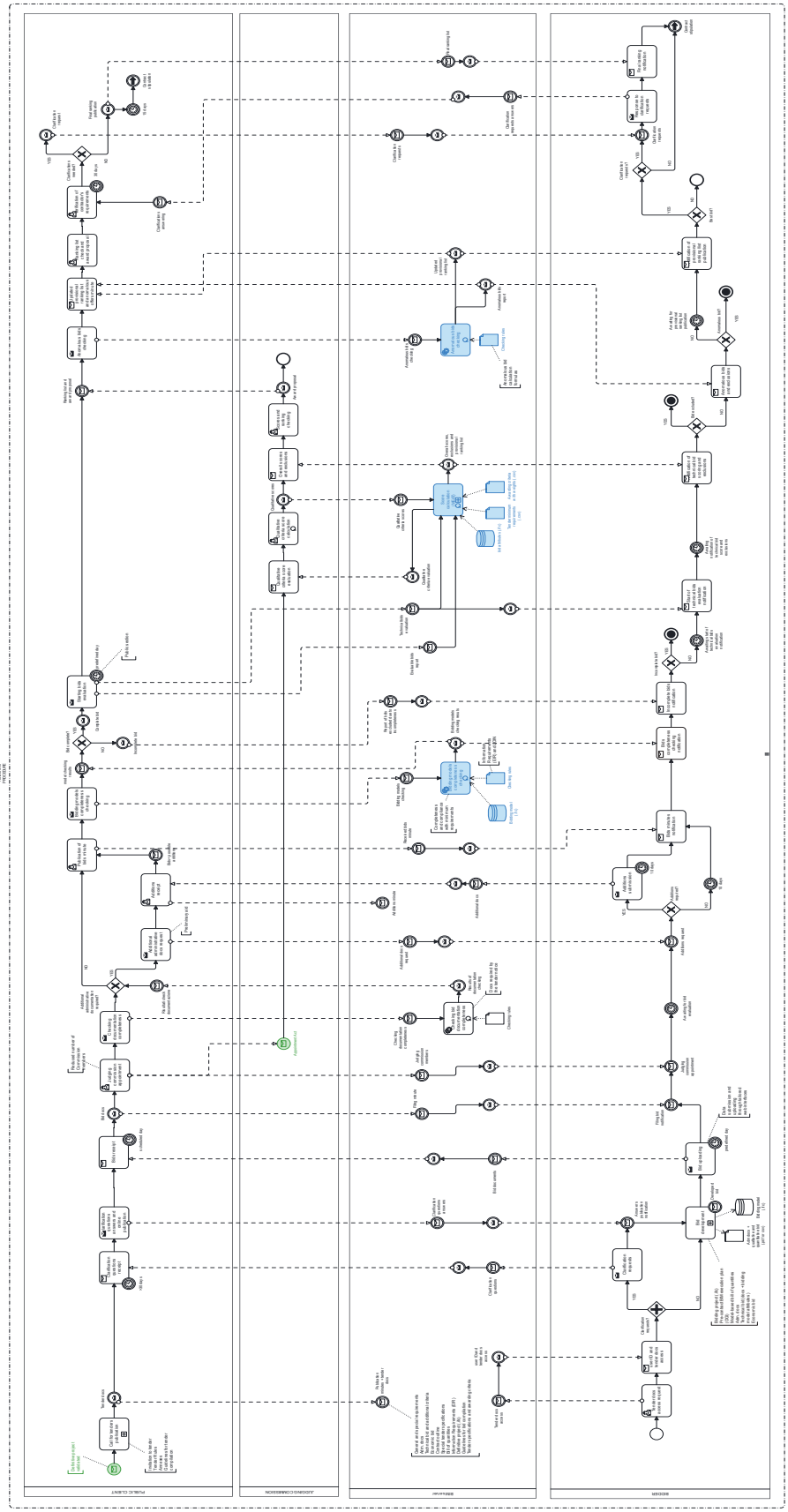

Figure 2: BPMN of the redefined model-based, open-source approach via web platform

support bidders with the correct development and submission of the models, ensuring to consider all required data and compliance with the IRs. It also helps the Public Client to gain more control over IRs and tender criteria fulfilment. Furthermore, thanks to the clear definition of the information requirements and the structure of the offer models, it is possible to make a real prototype of the building which allows to lay the foundations for valuable DTs, optimizing production costs and filling the gap in the literature regarding to the definition of IRs for DTs, in particular for DT Prototypes useful in the design and conception phase. The information requirements and the model can be enriched during the life cycle with different and dynamic information, coming from on field and sensors, leading to the incremental construction of the DT Instance to be used during the operation and maintenance phase. Starting with the development already from the tender phase, you have greater control over the necessary information, and you can also insert useful KPIs to evaluate performance, environmental impact, and production costs but also maintenance and disposal costs.

A further great innovation concerns the possibility of creating analytical dashboards, enabling a visual and easy comparison of project offers and performance. The users will visualize them via the web platform and interact to consult the data both at a global performance level and at a single criterion or sub-criteria level.

Conclusion and further developments

The research investigated the applicability of the BPMN 2.0 notation to formalize procurement processes and redesign them to improve digitalization and efficiency. It focused on the Italian public procurement sector which suffers from low decision speed and digitalization as it is still highly paper-based and prevents exploiting digital models. Firstly, it dealt with the formalization of the current Italian DB procurement with MEAT criterion through BPMN 2.0. Then, it was redefined in a model-based, open-source approach to improve interoperability, digitalization, data accessibility, and identification of automatable tasks. The proposed methodology to redefine the procurement procedure is replicable and adaptable also in other international contexts, modifying the IRs accordingly and adapting the process to the regulatory framework. The graphical representation of the process enabled understanding of the relationships between stakeholders with the identification of bidding models IRs. The next step of the research will deal with their formal definition in a structured way to define information protocols with their mapping in IFC, ensuring interoperability as required by regulations. The innovative model-based approach and its BPMN formalization provide also the ability to implement smart contracts, dynamically supporting processes, and blockchain integration. They will be considered to enable further automation, such as those related to administrative tasks (e.g. payments or permits), besides gaining more confidence enabling to trace data modification, information transactions, and responsibility, also obtaining data change history. The innovative approach requires disruptive interventions in the current procurement and tender procedures, both in terms of skills and IT equipment and infrastructures. It has not yet been tested through a real case study, but it will be in the future with process performance indicators, albeit complicated. It is currently under evaluation by experts in the sector and the results were discussed as expected impacts, but some are almost certain. Undoubtedly, the proposed innovative approach could streamline procedures currently devoid of automation and still based on a paper with the delivery of documents. The ability to submit models unlocks high potential. Above all, it enables automated model compliance checking with IRs currently difficult to be checked, such as environmental protocols, and semi-automated bids evaluation through MEAT. It also provides more informed decisions, based on objective data and scenario simulations, visualizing the evaluation of numerous criteria through analytical dashboards. A cost-benefit analysis is needed to identify the resources necessary for its implementation, even if it certainly provides savings and efficiency. It will also be necessary to review Public Clients skills, as well as their IT equipment, and a change management strategy made up of specific training courses. Finally, given the disruptive nature of the proposal, regulations, and standards need to be changed and implemented for its concrete adoption.

In conclusion, the formalization of the current procedure has highlighted how it is still paper-based and not designed to exploit digital tools and models. Revolutionizing current approaches is not easy, but it is essential for a breakthrough in the industry. Introducing digitalization through regulations is not enough, the technologies are available, but a redefinition of the management processes is required otherwise the potential of digitization will never be fully exploited. Public Clients could act as a leading force and guide the entire supply chain towards the concrete implementation of the digital and green transition.

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References

Afsari, K., Eastman, C. & Shelden, D. (2017) Building information modeling data interoperability for cloud-based collaboration: Limitations and opportunities. International Journal of Architectural Computing, 15(3), pp. 187–202.

Agenzia per la coesione territoriale (2018) Rapporto sui tempi di attuazione delle opere pubbliche.

ANAC https://www.anticorruzione.it/-/delibera-numero-332-del-20-luglio-2022

Armijo, A., Elguezabal, P., Lasarte, N., & Weise, M. (2021). A Methodology for the Digitalization of the Residential Building Renovation Process through OpenBIM-Based Workflows. *Applied Sciences*, *11*(21), 10429.

Borrmann, A., König, M., Koch, C., & Beetz, J. (Eds.). (2015). Building Information Modeling: Technologische Grundlagen und industrielle Praxis. Springer-Verlag.

Camunda. Camunda modeler. www.camunda.com

Consip,2017 https://www.acquistinretepa.it/opencms/export/sites/acquistinrete/documenti/Help_documentazione/Procedura_di_RdO_Off_eco3.pdf

Corneli, A., Naticchia, B., Carbonari, A. & Vaccarini, M. (2021a) A framework for development and integration of digital twins in construction. ECPPM 2021 – eWork and eBusiness in Architecture, Engineering and Construction. CRC Press, July, pp. 291–298.

Corneli, A., Naticchia, B., Spegni, F., & Spalazzi, L. (2021b). Combining blockchain and BPMN coreographies for construction management. In *EC3 Conference 2021* (Vol. 2, pp. 34-41). ETH.

Di Giuda, G. M., Villa, V., & Loreti, L. (2015). Il BIM per la gestione di una gara con il criterio dell'offerta economicamente più vantaggiosa-BIM to manage public procurement with award criterion Most Economically Advantageous Tender. *ISTeA.*, 1-4.

EU Commission (2017) Making public procurement work in and for Europe.

EU Commission (2019), Single Market Public Procurement

Grilo, A. & Jardim-Goncalves, R. (2011) Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective. Automation in Construction, 20(2), pp. 107–114.

Borrmann, A., König, M., Koch, C., & Beetz, J. (Eds.). (2015). *Building Information Modeling: Technologische Grundlagen und industrielle Praxis*. Springer-Verlag.

Gardini A, Bragadin M A, Naticchia B, Carbonari A and Corneli A 2020 BPMN 2.0 modelling for the management of the inspection of execution processes in construction Creative *Construction e-Conference* 2020 pp. 37-41 doi:10.3311/CCC2020-073.

ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling - Part 1: Concepts and principles

ISO 29481:2017 Building Information Models – Information delivery manual

ISO 16739—Industry Foundation Classes (IFC) for Data Sharing in the Construction and Facility Management Industries; International

Locatelli, M., Tagliabue, L. C., & Di Giuda, G. M. (2022). ArchiBERTo: a hierarchization quality objectives NLP tool in the Italian Architecture, Engineering and Construction sector. In Proceedings of 1st Workshop AIxIA 2022 (pp. 8-25).

Mc Kinsey Global Institute (2017) Reinventing-construction-A-route-to-higher-productivity-Full-report.

MIUR, PRIN (2017) A Distributed Digital Collaboration Framework for Small and Medium-Sized Engineering and Construction Enterprises pp. 1–23.

Object Management Group, Business Process Model and Notation. https://www.omg.org/spec/BPMN/

Oraee, M., Hosseini, M. R., Namini, S. B. & Merschbrock, C. (2017) Where the gaps lie: Ten years of research into collaboration on BIM-enabled construction projects. Construction Economics and Building, 17(1), pp. 121–139.

Pellegrini, L., Locatelli, M., Meschini, S., Pattini, G., Seghezzi, E., Tagliabue, L. C., & Di Giuda, G. M. (2021). Information Modelling Management and Green Public Procurement for Waste Management and Environmental Renovation of Brownfields. *Sustainability*, *13*(15), 8585.

Rezgui, Y., Boddy, S., Wetherill, M., & Cooper, G. (2011). Past, present and future of information and knowledge sharing in the construction industry: Towards semantic service-based e-construction. *Computer-Aided Design*, *43*(5), 502-515.

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. John Wiley & Sons.

Srećković, M., Šibenik, G., & Breitfuß, D. (2022). Capturing and Transforming Planning Processes for Smart Contracts. In *Blockchain for Construction* (pp. 75-88). Singapore: Springer Nature Singapore.

Sreckovic, M., Sibenik, G., Schützenhofer, S., Kovacic, I., Preindl, T., & Kastner, W. (2022, July). DiCYCLE: Rethinking the buildingsend-of-life. In *EC3 Conference 2022* (Vol. 3, pp. 0-0). University of Turin.

Succar, B., & Poirier, E. (2020). Lifecycle information transformation and exchange for delivering and managing digital and physical assets. *Automation in Construction*, *112*, 103090.

Von Rosing, M., White, S., Cummins, F. & De Man, H. (2015) Business Process Model and Notation-BPMN.