Toward a New and Sustainable Era of the Building Sector: Building Information Modelling (BIM)

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Abstract

This paper outlines the importance of sustainability as a determining criterion to be considered in the application of new technologies in the building sector and in the introduction of new agents and actors in the building process. BIM technology enhances both quality and sustainability in building because of the management of shared information in real time and its constant updating. It is estimated that BIM will contribute to sustainability in the building sector, with an estimated 15% reduction in waste volume and a 57% reduction in waste management costs.

Keywords

Sustainability, Building Information Modelling BIM, Construction, Sustainable Facility Manager, Lean Manager, ISO 19650.

I. Introduction[1]

This paper outlines the importance of sustainability as a determining criterion to be considered in the application of new technologies in the building sector and in the introduction of new agents and actors in the building process. To this end, it is important to bear in mind that the result of building activities (now referred to as an 'asset')[2] is dynamic and extends far beyond the completion and delivery of the constructed building. On the

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[1] This work is the result of collaboration between two research projects: ESCOP4Green ('Enhancing Sustainable Consumption and Production for the Green Transition'), an EU funded project (Next Generation) led by Professor Lucia Ruggeri (University of Camerino, Italy), and the National Research Project of Knowledge Generation IAREDI ('Artificial Intelligence and its impact on the real estate construction sector' (PID2021-124961NB-I00), funded by the Spanish Research Agency and led by Prof. Remedios Aranda and myself, both at the University Carlos III of Madrid (Spain). This work is an outcome of the research presented in New York in 2024 and Vienna 2023.

[2] This is the terminology used and consolidated by ISO 19650, the international standard for managing information throughout the lifecycle of a built asset using building information modelling.

contrary, the life of an asset begins long before design and building commence, and its life continues well beyond the handover of the building to the client, the new owner. This new dimension has led to the emergence of new players in the building industry and new methodologies. Moreover, in this last decade, different players and stakeholders in the building business (both traditional and emerging players) have experienced a profound shift in their relationship. This new way of working is extremely narrow, collaborative, digital, global, and ubiquitous. In few words: a more flexible, dynamic, and 360º vision of different problems and solutions. This not only facilitates real-time problem-solving but also enhances capacity to predict and address potential issues – immediate, future, or hypothetical – by applying state-of-the-art solutions. Finally, this methodology produces a dynamic digital twin of the asset. The digital twin is more than a simple model: it involves the exchange of information in real time between the asset (regardless of its dimension) and its digital twin.

It is easy to understand how this new technology and modelling tool may offer great benefits, but it also implies higher risks. The more reliant we become on this technology, the greater is the potential damage in the event of failure – whether due to human or non-human error. This is one of the reasons why there are new stakeholders in the building industry. This is also one of the reasons why there is a notable silence from the insurance stakeholders on this topic. Ultimately, we are all working with enormously powerful technologies, but without the safety and security guaranteed by a legal framework. This means that today we need to rely on general laws (contract law, liability law, etc.) and specific technical standards[3] as well as ISO 19650 – the 'international standard for managing information throughout the life cycle of a built asset using building information modelling (BIM)'. ISO 19650 consists of five parts that cover different phases of an asset's lifecycle, from planning and design to construction, operation, and maintenance. Moreover, the application of ISO 19650 must be complemented by other ISO standards relating to various issues, including the stakeholder's functions, health and safety

[3] The Spanish Government notes that (https://www.mapa.gob.es/en/desarrollo-rural/temas/gestion-sostenible-regadios/centro-nacional-tecnologia-regadios/normalizacion/organismos-normalizacion/iso.aspx) 'ISO is a network of the national standards institutes of 162 countries, on the basis of one member per country, with a Central Secretariat at its headquarters in Geneva (Switzerland) that coordinates the system. The International Organization for Standardization (ISO) is composed of governmental and non-governmental delegations subdivided into a number of subcommittees charged with developing guidelines that will contribute to environmental improvement. The standards developed by ISO are voluntary, given that ISO is a non-governmental organization and does not depend on any other international organization; therefore, it does not have the authority to impose its standards on any country'.

standards, IT and technological standards, environmental and energy standards, and sustainability matters, among others.[4]

Considering this new and complex reality, which poses a tough challenge to cover in this paper, the outline I will follow is as follows: (i) First, I will provide a brief overview of sustainability in the building sector, and the importance of the impact of the footprint and its evolution. (ii) Second, I will introduce some of the new key players in the building process, such as the Facility Manager and the Lean Construction Manager (LC). (iii) Third, I will present some basic characteristics of BIM, a revolutionary tool that employs a digital, collaborative, and predictive methodology. BIM has been applied in the building sector for several years and already offers some interesting insights into its future potential. (iv) Finally, I will end the paper with some concluding remarks.

II. Sustainability and Building Business: Sustainable Building?

'Sustainability' and 'building construction' have a difficult and complex relationship. Balancing the two involves addressing the need for building – which is essential for the development of human activity (housing, infrastructure, communication, leisure,[5] business, health, etc) – while minimizing the environmental impact and promoting global sustainability.[6]

[4] For example, ISO 15221; 15942; 15643; 16309; 41012; 16627; 15978; 11855, among others. We would just like to highlight ISO 15392 and 17680, which regulate respectively 'Sustainability in building construction' and 'Sustainability of construction works. Assessment of the potential for sustainable renovation of buildings'.

[5] This aspect was partially addressed by M.I. Feliu Rey and M.D. Sánchez-Galera, 'La cooperativa como motor de la sostenibilidad el turismo', in L. Mezzasoma and M.J. Reyes López, *Turismo y sostenibilidad* (Navarra: Ed Aranzadi, 2018).

[6] Sustainability in building construction can be explained as the commitment and consistency in the responsible consumption of resources (both in terms of quality and quantity) in construction so that the current generation does not suffer from the negative consequences of construction in their life, and future generations inherit sufficient resources and an environment as clean and healthy as the current generation did. M.S. Bajjou et al, 'The Practical Relationships between Lean Construction Tools and Sustainable Development: A Literature Review' *Journal of Engineering Science and Technology Review*, X (2017); S. Moradi and K. Kähkönen, 'Success in Collaborative Construction through the Lens of Project Delivery Elements' *Built Environment Project and Asset Management*, XII (2022); S. Moradi and K. Kähkönen, 'Sustainability Indicators in Building Construction Projects through the Lens of Project Delivery Elements', in *Proceedings of the World Building Congress (WBC) 27-30 June 2022* (Melbourne, Australia: Emerald Publishing, 2022); S. Moradi and P. Sormunen, 'Integrating Lean Construction with BIM and Sustainability: A Comparative Study of Challenges, Enablers, Techniques, and Benefits' *Construction Innovation*, XXIV, 189 (2024).

One of the objectives of the 2030 Agenda is precisely to build sustainable and resilient cities (SDG 11).[7] Indeed, the UN states that 'cities represent the future of global life (...). Urban sprawl, air pollution and limited public open spaces persist in cities. Sustainable development cannot be achieved without significantly transforming the way urban spaces are built and managed'.[8] This concern is also reflected in the EU's objectives for 2040 and in the 2050 Agenda.[9]

Clearly, this is a very complex, if not unsolvable, problem, especially for critical issues preventing the sustainable development of the building sector, e.g. increases in costs[10] and shortage of raw materials or inadequate implementation scenario. Therefore, solutions may well have to be considered in a new dimension: the process of digitalization of the building business.[11] It should be noted that the impact of building on sustainability

[7] Wopke Hoekstra, EU Commissioner for Climate Action, said: 'In a climate-neutral Europe, we need to be able to heat and cool our homes and buildings with minimum emissions. We have the technologies to do this, but we need to create a stronger business case for renovations. The new Energy Performance of Buildings Directive will help mobilise additional finance and boost construction value chains. Together we can help homeowners and businesses renovate to save money and prepare for a net-zero future', available at https://www.esgtoday.com/eu-adopts-law-requiring-all-new-buildings-to-be-zero-emissions-by-2030/ (last visited 3 September 2024).

[8] In fact, the EU Climate Target insists on this point. In February 2024, the European Commission presented its assessment of a 2040 climate target for the EU. The Commission recommended reducing the EU's net greenhouse gas emissions by 90% by 2040 compared to 1990. The 2040 climate target will reaffirm the EU's determination to fight climate change and will shape our pathway beyond 2030 to ensure that the EU achieves climate neutrality by 2050. The goal of climate neutrality is at the heart of the European Green Deal and is a legally binding objective set out in European Parliament and Council Regulation 2021/1119/EU of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 [2021] OJ L243, 1-17, also known as the European Climate Act. In any case, the EU's climate target for 2030 is to reduce net greenhouse gas emissions by at least 55% compared to 1990. The 2040 climate target is our next intermediate step on the road to climate neutrality.

[9] This justified and necessary concern is manifested in a large and dense body of legislation such as European Parliament and Council Directive 2024/1760/EU of 13 June 2024 on Sustainability Due Diligence for companies and amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859 [2024] OJ L series.

[10] For an analysis of the capital cost barrier to sustainable construction and of a tactical framework to reduce costs and ensure sustainable buildings' whole-life costs, see M. Nasereddin and A. Price, 'Addressing the Capital Cost Barrier to Sustainable Construction' *Developments in the Built Environment*, 7 (2021), available at https://www.sciencedirect.com/science/article/pii/S2666165921000089.

[11] Obviously, in turn, the inevitable environmental impact of digitalization must be considered. See T.L. Friedmann, 'We are Openings the Lids on Two Giant Pandora's Boxes' *The New York Times*, available at https://www.nytimes.com/2023/05/02/opinion/ai-tech-climate-change.html (last visited 3 September 2024). On this article, Friedmann (three time winner of Pulitzer Prize) says: 'One of these Pandora's boxes is labelled "artificial intelligence", and it is exemplified by the likes of ChatGPT, Bard, and AlphaFold, which testify to humanity's

is not a one-off event: on the contrary, the impact extends over the various phases of building activity, ie pre-planning,[12] planning, design, supply of materials, construction, maintenance and upkeep of the building, occupancy by tenants, possible repairs and structural modifications. Additionally, factors such as energy consumption and efficiency[13] play critical roles. It is therefore important to consider the building as a unit (asset), with its own life and whose impact on the environment and sustainability must be considered at every stage.[14] This also applies to the total or partial ruin or destruction of the building.

In short, we cannot lose sight of the growing importance, also in terms of reputation, of sustainability in the complex reality of building construction. This leads us to the next section: the emergence of new subjects (actors and stakeholders) whose primary mission is to ensure that the evolution of the asset conforms to preset parameters, including

ability for the first time to manufacture something in a godlike way that approaches general intelligence, far exceeding the brainpower with which we evolved naturally. The other Pandora's box is labelled "climate change", and with it we humans are for the first time driving ourselves in a godlike way from one climate epoch into another. Up to now, that power was largely confined to natural forces involving Earth's orbit around the sun. For me the big question, as we lift the lids simultaneously, is: What kind of regulations and ethics must we put in place to manage what comes screaming out?'.

[12] For example, the proposed expansion of Barcelona airport was stopped in the initial phase precisely because of the environmental impact on the lagoon protected by the Natura 2000 network. cf *Diario El Mundo*, available at https://www.elmundo.es/economia/2021/06/12/60c3afe821efa062568b4652.html.

[13] In this sense, the following illustrate the idea properly: 'Buildings are responsible for approximately 40% of the energy consumption and 36% of the CO_2 emissions of the EU. On average Europeans spend 90% of their time indoors, and the quality of the indoor environment affects health and wellbeing. Two-thirds (65%) of Europe's building stock was built before 1980: about 97% of the EU's buildings must be upgraded to achieve the 2050 decarbonization goal [1], but only around 1% are renovated each year. Buildings have the potential to drive flexibility in the energy system, through energy production, control, storage and demand response, as well as green charging stations for electric vehicles; but this can only happen if a systemic upgrade of the building stock is achieved. A highly efficient, technically equipped and smarter building stock could be the cornerstone of a decarbonized energy system. EU legislation provides a clear framework for Member States to support the implementation of this interconnected system'. M. Fabbri et al, *A Guidebook to European Building Policy Key Legislation and Initiatives* (Buildings Performance Institute Europe, 2020), available at https://www.bpie.eu/wp-content/uploads/2020/08/BPIE_Guide-on-Building-Policy_Final.pdf (last visited 3 September 2024).

[14] The GBCe Country Report 2022: on the state of sustainable building urgencies in Spain identifies six urgencies to transform the sector: 'Acting on decarbonization, circular economy, health, biodiversity, integral renovation and resilience of society is imperative for a sector, the building sector, which is required to change its system to respond to the new environmental, economic, social and institutional challenges [...] Each of these urgencies has a different level of development and understanding and is at a different stage of change. But at the same time, they are deeply interlinked', available at https://gbce.es/documentos/GBC_informe_2022_Digital.pdf.

sustainability criteria. Among these, the Facility Manager (FM) assumes special importance as they are present in almost all phases of the asset. I will also make a brief reference to the Lean Construction Manager (LC) because of its growing role and impact on sustainability.

III. Facility Manager and Lean Construction Manager: New Players in the Building Industry[15]

1. Facility Manager

There are numerous definitions of Facility Manager (FM).[16] Castellanos Moreno[17] offers a detailed overview of the evolution and different perspectives of the figure. However, the basic element of all of them lies in the integrated management of asset[18] maintenance, management and conservation. The aim is to maximize efficiency, profitability, and cost savings throughout the asset's lifecycle, which begins in its pre-construction phase and extends until its demolition or recycling. This comprehensive management, therefore, encompasses every aspect,

[15] Spain regulates the building sector at the national level through the 1999 Law on Building Regulation, which defines and controversially restricts the list of recognized 'building agents'. However, the truth is that building activity is becoming increasingly complex and international, leading to the emergence of new agents, many of whom are of foreign origin. The best known are, among others, the Project Manager, the Forward Funding Manager, and the Facility Manager. Additionally, other new agents such as the Lean Manager and the Risk Manager, with very specific roles that respond to the business side of building development, have emerged. Obviously, although all of them assume a relevant role in terms of the sustainability criteria of the asset throughout its different phases, it is not possible to cover all stakeholders and actors here. For example, public authorities (governments/regulators/local authorities) play a fundamental role in granting or denying licences, permits and authorizations necessary for an asset's success. Other stakeholders include the Risk Manager, building users and owners, design teams (engineering & architecture of buildings), contractors and builders, manufacturers of construction products, deconstruction and demolition teams, investors, developers, and insurance providers.

[16] 'Literature is replete with FM definitions', claims E. Parms et al, 'The Building Information Modelling Trajectory in Facilities Management: A Review' *Automation in Construction*, LXXV, 45-55 (2017).

[17] M. Castellanos Moreno, 'La responsabilidad social como valor añadido del facilities manager en la gestión del patrimonio inmobiliario' (2013), Doctoral thesis supervised by Prof A.E. Humero Martin, School of Architecture, Polytechnic University of Madrid. Thesis published and consulted in the online institutional repository of the University.

[18] The three key components of facilities management are the integration of people, places, and processes. By bringing these three elements together, facilities managers can create a work environment that is conducive to increased productivity and improved quality of life for employees. Parms, Edwards, Sings (2017) state: 'These skills encompass diverse roles and duties may include the strategic planning and management of: plant operations; computer systems analysis; building assets; interior operations; and day-to-day tactical operations of assets and staff'. Of course, information is critical for supporting efficient and effective building maintenance and day-to-day operations.

including space utilization, facilities, human resources and, of course, sustainability. This requires a thorough knowledge of the asset, also in the project phase, and the preparation of an appropriate strategic plan. The FM is present throughout the asset's lifecycle and collaborates closely with other actors such as the Project Manager. This has given rise to the role of the Sustainability Facility Professional (SFP) as a speciality within the functions of the FM,[19] referring specifically to the management of the sustainability of the asset. The SFP's responsibilities include sustainable management of energy,[20] water, waste, and the materials and resources used by an asset. Sustainable Facility Management aims to minimize the negative environmental impacts of the building sector. In fact, 'Sustainable Facility Management (SFM) is a unique process that offers a Facility Manager the authority to make structural, architectural, and operational changes that reduce the negative impact of buildings on their occupants and the environment'.[21] SFM 'encompasses several principles, including energy and water efficiency, waste management, ecological design, use of sustainable materials, user perspective, indoor air quality assurance, appropriate landscaping, enhanced quality of life, financial aspects, and strategic maintenance'.[22]

The recent EU Directive 2024/1760 of 13 June 2024 on Sustainability Due Diligence for companies has significantly reinforced the role of the SFM, elevating its prominence even further. Indeed, Directive 2024/1760, Recital (19) says: 'Therefore, the main obligations in this Directive should be obligations of means. The company should take appropriate measures which are capable of achieving the objectives of due diligence by effectively addressing adverse impacts, in a manner commensurate to the degree of severity and the likelihood of the adverse impact'. This statement is applicable to construction and, of course, more specifically to the SFM.[23]

[19] IFMA's Sustainability Facility Professional (SFP) is an assessment-based certificate programme that offers specialized certification in sustainability. It is also an opportunity for FMs with an interest in efficiency, data-driven decision-making and sustainable practices to gain recognition and expertise. Earning the SFP designation enables individuals to contribute to their organization's economic, environmental and social performance (https://www.ifma.org).

[20] For instance, according to the US Green Building Council, buildings account for 36% of total energy consumption in the United States.

[21] J.P. Fennimore, *Facility Type and Management Methods. Sustainable Facility Management: Operational Strategies for Today* (London: Pearson Education, 1st ed, 2014), 1-31; see also G. Alfalah and T. Zayed, 'A Review of Sustainable Facility Management Research' *Sustainable Cities and Society*, LV (2020).

[22] D. Kincaid, *Adapting Buildings for Changing Uses: Guidelines for Change of Use Refurbishment* (London-New York: Taylor &Francis, 2004).

[23] See Art 29 (Civil liability of companies and the right to full compensation) European Parliament and Council Directive 2024/1760/EU.

2. Lean Construction Manager (LC)

In 1992, the Center for Integrated Facility Management at Stanford University published a Technical Report signed by Lauri Koskela, entitled 'Application of the New Production Philosophy to Construction Technologies'.[24] This report basically advocated for a shift in the vision of construction, proposing that it should be seen as a flow of processes instead of an isolated activity.[25] Lean construction[26] is a project delivery process that uses lean methods to maximize stakeholder value and reduce waste by emphasizing collaboration between teams on a project.

The goal of Lean Construction (LC) is to increase productivity, profitability, and innovation in the industry.[27] LC is born for site execution but extends to all stages of the project. In other words, as Koskela[28] noted, 'there are two main processes in a construction project: (a) Design process: is a stagewise refinement of specifications where vague needs and wishes are transformed into requirements, via a varying number of steps, to delayed design. Simultaneously, this is a process of problem detection and solving. It can be further divided into individual subprocesses and supporting processes. (b) Construction process: is composed of two different types of flows: (i) Material process consisting of the flows of material to the site, including processing and assembling on site. (ii) Work processes of construction teams. The temporal and spatial flows of construction teams on site are often closely associated with the material processes'.

In addition, LC activity promotes greater efficiency, waste reduction, team confidence, customer satisfaction, collaborative risk management, fair delivery of profits and improved safety on projects. A modern and contemporary re-reading of the purpose of LC must surely include

[24] Available at https://stacks.stanford.edu/file/druid:kh328xt3298/TR072.pdf.

[25] L. Koskela, *Technical Report* (Stanford University, 1982), 5: 'The ideas of the new production philosophy first originated in Japan in the 1950s'. The most prominent application was the Toyota production system. The basic idea in the Toyota production system is the elimination of inventories and other waste through small lot production, reduced set-up times, semiautonomous machines, co-operation with suppliers, and other techniques (citation of Monden 1983, Ohno 1988, Shingo 1984, Shingo 1988)'.

[26] X.M. Brioso Lescano, 'El análisis de la Construcción sin pérdidas (Lean Construction) y su relación con el Project & Construction Management: Propuesta de regulación en España y su inclusión en la Ley de Ordenación de la Edificación' (2015), Doctoral thesis supervised by Prof Dr A.E. Humero Martin, School of Architecture, Polytechnic University of Madrid. Thesis published and consulted in the online institutional repository of the university.

[27] An example of this is the T-30 Hotel (China) which was built using Lean. This 30-storey hotel was built in just 15 days and included a number of innovative features. Lean aims to maximize value for stakeholders, while minimizing waste and improving efficiency across the board (see X.M. Brioso Lescano).

[28] L. Koskela, n 25 above, 38.

advocating sustainability during the Flow of Construction, (that is, a movement that is smooth and uninterrupted, as in the flow of work from one crew to the next[29]), where this is translated into cost, value and time.

The functions assigned to FM and LC are further enhanced in a BIM environment, as this triangle represents a real paradigm shift[30] in the building industry, moving away from individuality and local optimization toward team spirit, aligned interests, and project optimization.

IV. Building Information Modelling (BIM) and Sustainability

Directive 2014/24/EU[31] states in Art 22: 'For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar'. Thus, with the expression 'building information electronic modelling tools or similar', for the first time in the European Union, specific mention is made of the usefulness and convenience, later converted into necessity, of using BIM. In addition, the European directive also stipulates that contracting authorities must offer alternative means of access until these tools become widely available. Finally, this directive requires Member States to put in place some provisions requiring the use of these systems in public procurement contracts, with the following objectives: cost savings[32] (economic and time), an economic boost to the building sector, and the improvement of sustainable design.[33] In other

[29] S. Moradi and P. Sormunen, 'Integrating Lean Construction with BIM and Sustainability: A Comparative Study of Challenges, Enablers, Techniques, and Benefits' *Construction Innovation*, XXIV, 190 (2024).

[30] S. Moradi et al, 'A Competency Model for the Selection and Performance Improvement of Project Managers in Collaborative Construction Projects: Behavioral Studies in Norway and Finland' *Buildings*, XI, 10004 (2021).

[31] European Parliament and Council Directive 2014/24/EU of 26 February 2014 on public procurement and repealing European Parliament and Council Directive 2004/18/EC [2014] OJ L94/65.

[32] The EUBIM Task Group, supported by the European Commission, published in 2017 a handbook for the introduction of BIM methodology by the European public sector, in which it estimates – in that year – that the use of BIM allows savings of around 10-20% of construction expenditure. Today, this percentage of savings is much higher. The increasing application of BIM makes the total savings in the building sector very significant. However, the analysis carried out by the Interministerial BIM Commission on the basis of the 2022 tenders published on the Public Sector Procurement Platform foresees a significantly higher potential implementation of BIM, which estimates that between 20% and 25% of the estimated value of the tender of AGE and its public bodies and related or dependent public law entities is susceptible to the use of BIM.

[33] European Commission, 'Making public procurement work in Europe and for Europe' (Communication) COM(2017) 572, alludes to the transformative potential of using BIM methodology for the building sector: 'a specific approach (to strategic public

words, Directive 2014/24/EU fosters the gradual yet steady implementation of BIM.[34]

What exactly is Building Information Modelling (BIM)?[35] Clearly, BIM is *not* a simple software tool that allows the evolution of classic modelling systems in a digital format. It is not an actor in the building industry: BIM is not an agent similar to, for example, a project manager, a developer, or a builder. Rather, BIM is a working methodology for the creation and management of a project which centralizes all the information generated by all the agents involved in the lifecycle of an asset. This collaborative approach makes BIM a key tool in project management. Naturally, BIM methodology requires the intervention of professionals with specific

procurement) is needed in priority sectors, such as Construction [...]. Initiatives and tools such as [...] Building Information Modelling [...] are already in place'.

[34] The aforementioned Directive is transposed in Spain through the Public Sector Contracts Law 9/2017, which regulates the administrative procedure through which a public body develops a contracting process of a different nature or object, such as works, project tenders or related services (Works Management, Health and Safety coordination, Quality Control, etc). Section six of the fifteenth additional provision of this law, entitled 'Rules on the means of communication to be used in the procedures regulated in this law', states that 'for public works contracts, works concession contracts, service contracts and project tenders and in mixed contracts that combine elements of these, contracting authorities may require the use of specific electronic tools, such as Building Information Modelling (BIM) or similar tools'. In other words, Public Sector Contracts Law 9/2017 allows but does not (at that date) oblige public bodies to require the use of BIM methodology in public tenders by including it in the tender specifications. In 2018, the Spanish Government issued Royal Decree no 1515 of 28 December 2018, establishing the Interministerial Commission for the incorporation of the BIM methodology in public procurement. This Commission was tasked with drawing up a Plan for the Incorporation of the BIM Methodology in the public procurement of the General State Administration, setting minimum thresholds for its mandatory application and outlining actions for its gradual and progressive implementation. This Plan was approved on 28 December 2023. On the other hand, in Spain, Royal Decree 472/2019, published in the Official State Gazette on 2 August 2019, regulates the direct granting of subsidies to various professional associations and general councils of professional associations to support training on BIM methodology during the 2019 budget year. In 2022, the Spanish Law on Architectural Quality stated that 'the use of specific electronic tools, such as digital building information modelling (BIM) methodologies, will be encouraged in public sector projects' which 'will facilitate the drafting of projects, construction management and management of the execution of the work and the use and maintenance of architecture'. More recently, in 2023, as part of this slow but unstoppable implementation of BIM in Spain, Order PCM/818/2023 of 18 July (BOE 20 July 2023) was published, approving the Plan for the Incorporation of the BIM Methodology in the public procurement of the General State Administration and its public law entities.

[35] BIM is also defined in Fundamentos BIM en la contratación pública, published by the Spanish BIM Interministerial Commission, available at https://cvp.mitma.gob.es/fundamentos-bim-para-la-contratacion-publica-2.

professional qualifications: architects and engineers with specialized knowledge of how BIM works.[36]

BIM is a collaborative work methodology for the management of building or civil works projects through a digital model. This digital model serves as a large database that makes it possible to manage the elements that make up the asset's infrastructure throughout its lifecycle. The BIM methodology represents a real technological revolution for the building industry's production and management processes, aiming to centralize all project information in a digital model created by all its agents. This tool makes it possible to build more efficiently, reducing costs while allowing designers, builders and other agents involved to work collaboratively. BIM is the evolution of traditional plan-based design systems, as it incorporates: (i) geometric information (3D – represents the information of the architectural design and each engineering aspect involved in order to obtain a detailed geometric representation of each part of the building –); (ii) time (4D – allows the execution process of a project to be known and controlled through simulations, etc –); (iii) cost (5D – control of costs and estimation of expenses of a project with a direct impact on its profitability –); (iv) sustainability or environmental (6D – behaviour of the project allowing for the creation of variations in materials, fuels, etc –); and (v) maintenance (7D – managing the lifecycle of the project: inspections, maintenance, etc). The use of BIM goes beyond the design phase, extending into the execution of the project. BIM is a digital and dynamic representation of a projected and/or constructed object (buildings, bridges, roads, etc) through the structured, coordinated, and coherent use of a reliable database. This allows for decisions to be taken throughout the lifecycle of the object, starting with the design and ending with its demolition or decommissioning.

BIM is regulated in the ISO 19650 standard where BIM is defined as the use of a shared digital representation of a built asset to facilitate the processes of the design, construction, and operation of the asset and to provide a reliable basis for decision-making. BIM works with a single digital model,[37] which contains all relevant information about the asset. This improves all construction processes, avoiding errors and inconsistencies that can arise from using different models for the partial description (structures, installations, structural, and physical enclosures).

[36] In this regard, see Spanish Royal Decree 472/2019 (BOE 2 August 2019), which regulates the direct granting of subsidies to various professional associations for BIM methodology training.

[37] It is important to underline that a digital mock-up is not a static representation of the project in digital format, but a dynamic representation of all phases of the life of an asset, its design, and implementation. The information in the digital model is interactive and dynamic. Today it has evolved into what is known as a digital twin.

The different intervention of each stakeholder and agent responds to each phase or cycle attributed to them (which may be several), and of

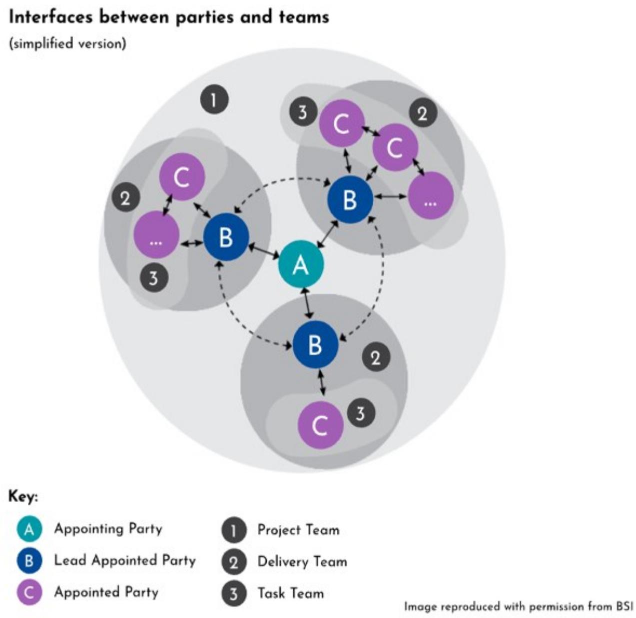
course, also to the special contents assigned to it. These contents may coincide – totally or partially – with several complementary tasks shared by different actors. The information provided, shared, verified and accepted (or refused) in each dimension implies a very high degree of predictability of the future evolution of the asset (short, medium, and long term) and its consequences (cost, time, sustainability, maintenance, and thus makes a forecast on its evolution) close to certainty. This is a complex and collaborative intervention where all agents are involved in each different phase of the BIM methodology.

Information is one of the axes of BIM. This information (in each dimension) is sought, analysed, selected, contrasted, modified, approved (and even rejected) and shared by different human teams. This implies the sophisticated management of this information. Therefore, prior to initiating a search for information, the Appointing Party (ie the owner, or asset developer or builder) must establish a set of requirements about who can access and modify the information, when they can do so, and the reasons for doing so, or in any other way affect the information (including but not limited to the asset's requirements (AIR)) on behalf of the organization (OIR), teams, employers (EIR), and other stakeholders.

Following this, the management of Asset Information (AIM) and Project Information (PIM) comes into play.

The BIM structure is organized around key people (actors) with different roles and functions: (i) the Appointing Party (triggers action and receives the information); (ii) the Lead Appointed Party (leads the action by leading the production of information); (iii) the Appointed Party (produces and delivers the information under the leadership of the Lead Appointed Party).

These roles form different hierarchical teams: (i) the Project Team (composed by the Appointing Party); (ii) the Delivery Team (composed by the Lead Appointing Party); (iii) the Task Team (composed by the Appointed Party and – optionally – by the Lead Appointing Party), as shown in the following graph:



Coordination between the different teams.

Successive and/or simultaneous flows.

Bidirectionality

Project Team structure (1), composed of some Delivery Teams (2) and Task Teams (3). Information exchanges can be internal (dotted line) or external (solid line). Source: Norma UNE-EN ISO 19650-2:2019.

This structure, as outlined by ISO 19650, also dictates a clear distribution of roles and responsibilities among the different teams.

For example, FM or SFM could be part of both the Task Teams (searching information) and the Delivery Teams (involved in planning, searching, authorizing or rejecting the information provided by the Task Team, etc). FM or SFM responsibilities would change according to their assignment (or not) to different Teams.

V. Conclusion

BIM technology is a tool that enhances the quality and sustainability of building projects as a result of the real-time management of shared information and its constant updating (Common Data Environment CDE, ISO 19650). The old scheme of the verticality of information is replaced by a horizontal, collaborative, and predictive model.

The use of BIM is estimated to contribute to sustainability in the construction sector by reducing up to 15% of waste volume and up to 57% of waste management costs ('European Construction Sector Observatory', 2021).

As stated in the Triennial Report on Public Procurement in Spain in 2021, 2022 and 2023,[38] the BIM methodology allows for a single source of information, fosters close collaboration among all stakeholders, and supports digital and collaborative management of information throughout the entire lifecycle of an asset. This also allows for more sustainable projects, the earlier detection of project errors, and more accurate drafting of technical specifications, which in the long run means fewer contract modifications and better and more sustainable contract execution. From an SPC point of view, the delivery of more sustainable projects and infrastructure will be more efficient. In short, it contributes to reducing waste or to optimal waste management, as well as to the improvement of the environmental performance (eg energy efficiency) of buildings and infrastructure (as it allows for the optimization of designs to reduce resource consumption or the use of more sustainable materials). The proper application of BIM methodology is likely to contribute to reducing environmental externalities in public procurement, among other green benefits.

While BIM presents a promising landscape for sustainability, it is not without risks, yet it is an area that deserves further exploration.

[38] Ministerio de Hacienda, Gobierno de España, Date of publication on the Transparency Portal: 6 August 2024, available at https://transparencia.gob.es/transparencia/transparencia_Home/index/MasInformacion/Informes-de-interes/Hacienda/InformetrienalContratacionPublica21-22-23.html (last visited 16 August 2024).