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The Project Manager's Core Competencies in Smart Building Project Management

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Abstract: Project manager competencies have been widely discussed in the literature. Although many works present lists of competencies for project managers, specific competencies for smart buildings were not found. This work aimed to identify the main competencies of project managers for the management of smart building projects. The methodology consisted of a two-step approach using the guidelines of preferred reporting items for systematic reviews and meta-analysis (PRISMA) to perform broad and detailed bibliographic research. Initially, a literature review was carried out to identify the main research fields related to the management of smart building projects and the specificities of these fields that can influence the management of this type of project. Next, these specificities were related to the competencies of project managers mentioned in the literature, to identify a set of more relevant competencies for project managers of smart building projects. The results showed that the main research fields are related to scope, risks, costs, schedule, technologies and systems, sustainability, and general characterization, which consider objectives, barriers, challenges, and regulations. They also showed that the most relevant competencies for managing smart buildings projects are technical competencies, leadership, communication, budgeting, attitudes toward risk, strategic management, organization, and specifying real requirements. These findings show the importance of hard and soft skills for managing smart building projects.

Keywords: project manager; project management; project success; competencies; smart building; intelligent building; smart construction

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1. Introduction

The competencies of project managers have been the subject of several studies over the past decades. Although there are competencies that are frequently mentioned in the lists of competencies found in the literature, the particulars of each project demand essential and specific competencies from project managers [1]. This applies to the management of smart building projects, since they are usually developed in a multidisciplinary environment, with rapid changes and a strong influence from technological innovations.

Since the emergence of smart buildings in the 1980s, different requirements have been incorporated into their design, indicating the dynamism of the concept and demanding multidisciplinary knowledge on the part of project managers. Such requirements are present in the smart building concepts proposed by various authors and institutions.

Although several smart building concepts have been proposed, no consensual definition encompasses all the necessary aspects for a building to be considered intelligent [2–4].

Understanding the evolution of the concept is important for understanding the core competencies that smart building project managers need, as the meaning of each concept can represent requirements to be included in the project.

A significant portion of the rapid changes in smart buildings occur due to the strong influence of technological innovations, present since the first mentions of smart buildings and constantly evolving. Innovations incorporated into smart buildings may represent barriers for project managers, such as the confidence to utilize new and untested technologies and the need for trained personnel to execute such technologies [5]. Allied with this are the constraints typical to projects, such as resources and schedules. This context has influenced both the scope of the product (the building itself) and project management.

From a broader point of view, the project manager concept adopted in this work is the one described in the PMBOK Guide as "the person designated by the performing organization to lead the team responsible for achieving the project objectives" [6]. However, it is important to emphasize certain characteristics and delimitations. Concerning the relationship with the performing organization, the concept adopted only considers what is presented in the PMBOK as "strategic and business management skills", focusing on the business model. Within the scope of this work, this means that the project manager must have knowledge and information about the organization that makes it possible to align the project with the company's strategies, mission, goals, and objectives. Thus, this does not include competences that may be required by other aspects of the relationship with the company, such as those related to legal liability [7,8] and work contracts. With regard to the project, the project manager must have competencies that make him capable of working on the project's particularities from the perspective of the knowledge areas of project management presented in the PMBOK. For example, managers have to deal with the fact that the risks of smart buildings can be higher [9], as well as the construction costs [5], and that the lack of a consensus on the smart building concept can impact the definition of the scope of the project. In this context, the responsibility that this work considers for the project manager is associated with the success of the project; that is, he is responsible for making the project achieve the planned results using the metrics established for each knowledge area of project management, in accordance with the organizational strategies, goals, and objectives. The concept adopted in this work can be identified in most articles that address the competencies of project managers. Thus, the findings of this work can be used by all project managers of smart building projects.

Smart buildings can be influenced by factors and requirements that drive the project and incorporate new concepts. For example, Froufe [10] identified 11 drivers that combine to increase building intelligence when correlated to eight SB systems, and Anglés [11] highlighted the ability of the regulatory requirements present in the official documents of each country to directly or indirectly affect the design of intelligent buildings.

Smart building requirements influence project management. For example, defining the project's scope is one of the first steps in project management and, as can be seen, presents the challenge of identifying and including the main requirements of the smart buildings. The range of requirements to be considered is wide, depending on the specificities of the smart building, such as the use of materials and technologies that are more expensive [5] and higher risk [9], and the dynamism of the environment in which they are inserted. Project management is also subject to barriers represented by the requirements of the SBs (Ghansah [12], Ghansah [13]).

Conventional buildings can also become intelligent with, for example, the application of new technologies such as the Internet of things (Internet of things) [14]. Other technologies such as digital twins and building information modeling (BIM) have been considered. Digital twins are virtual representations that can change the internal and external conditions detected by sensors connected to elements. Building information modeling is widely used in design, construction, and operation [9]. Pavón [15] showed the possibility of increasing the intelligence and sustainability of conventional buildings using techniques such as building information modeling (BIM) and facilities management (FM). The renovation of

buildings has also been a focus of much attention by the European community. Among the objectives, the importance given to increasing the accessibility, resilience, and intelligence of buildings stands out.

Hard and soft skills are demanded from project managers [1]. Hard skills are those associated with technical aspects of work execution, while soft skills are related to "interpersonal, human, people, or behavioral skills, and emphasize personal behavior and managing relationships between people" [16]. Do Vale [1] identified four categories (contextual, managerial, technical, and behavioral) of individual competencies for project managers. Zheng and Qiang [17] identified ten "competence-related topics including technical skills (work experience, professional skills, and information technology application), managerial competencies (procurement management, risk management, external stakeholder management, site management, environment management, and team management), and organizational skill". Lambrechts et al. [18] identified strategic management and action, diversity, interdisciplinarity, and interpersonal aspects as individual sustainability competencies that are the most reported. Tabassi et al. [19] showed that leadership competencies impact the success criteria of sustainable buildings. Attakora-Amaniampong et al. [20] concluded that the competencies related to project cost management, project risk management, and project quality management are the most important. Crispim et al. [21] identified patterns of project risk management practices and concluded that goal-related practices are the most used. Mirza et al. [22], in their study on the meaning of scope for project success, showed that the distinction between project and product scope can increase the chances of project success. Abdelmassih et al. [23], when researching the relationship between project managers' competencies and project time and cost dimensions, showed that risk management skills are associated with project cost and time. Smith et al. [24] addressed BIM and project cost management, presenting the core competencies; meanwhile, Sang et al. [25], in their study on skills for project managers in green construction, explained the main factors needed for the success of green buildings.

Alvarenga et al. [26] presented the broadest study on the competencies of project managers. In a comprehensive and detailed literature review, they analyzed extensive lists of competencies, to identify the main competencies project managers need to achieve project success. They also evaluated the correlations between these and underlying competencies, presenting the most important competencies.

Several lists of competencies have been proposed to support the activity of project managers in the most varied types of project, covering hard and soft skills. Competency lists found in the literature comprehensively address competencies [1,27] in specific areas of application, such as industry [28], construction [17], eco-design building projects [18], sustainable construction projects [19], and project-specific attributes, such as success [26,27].

Although several lists have been proposed under general and specific approaches and though smart buildings are an increasingly present reality in cities around the world, studies in the literature on the competencies of project managers when the focus is on smart building projects were not found.

This work addresses this gap and contributes to the literature regarding project management competencies and smart buildings, by aiming to identify the main research fields related to smart building project management, the specificities of these fields that can influence the management of this type of project, and the main competencies of project managers demanded by smart building project management. By identifying the research fields related to smart building project management, this work contributes to project managers acquiring new knowledge that can support their activities and contribute to the achievement of project success.

By defining the main competencies demanded from the project managers of smart buildings from the a traditional range of competencies, this work also contributes to the reduction in the extensive lists of competencies associated with the success of a project and provides a direction for the competencies that are directly related to the main fields of smart building research. This contribution aligns with the statement by [29] that exercising

a relatively small range of skills or areas of competence differentiates effective leaders from other leaders. This work also contributes to strengthening the intelligent building domain by addressing characteristics and specificities that impact the successful management of this type of project.

This article is structured as follows: Section 2 presents the methodological procedures of the research. Section 3 discusses the main research fields related to smart building projects, identifies the main specificities of smart building project management, and correlates the main research fields and specificities of smart buildings to the competencies needed by project managers. Conclusions are provided in Section 4.

2. Materials and Methods

The research question of this study was "In the context of numerous and extensive lists of competencies proposed for project managers in the literature, is it possible to identify a set of competencies that are most relevant for project managers of smart buildings?". The hypothesis investigated was that the specificities of intelligent building project management make some competencies more important for managers of this type of project.

The methodology consisted of a two-step approach using the guidelines of preferred reporting items for systematic reviews and meta-analysis (PRISMA) to perform broad and detailed bibliographic research. Initially, a literature review was carried out to identify the main research fields related to the management of smart building projects and the specificities of these fields that can influence the management of this type of project. Next, these specificities were related to the competencies of project managers mentioned in the literature, to identify a set of more relevant competencies for project managers of smart building projects.

2.1. Identification of Smart Building Fields

The main smart buildings fields and their approaches were identified and characterized in this step based on a broad and detailed literature review. The preferred reporting items for systematic reviews and meta-analysis (PRISMA) recommendations were considered [30]. The bibliographical research was carried out on the Web of Science, Scopus, Scielo, and the websites of the leading scientific publishers, considering works published in the last ten years. Hence, the content was the most representative of the current reality. The references of works considered relevant were also consulted.

The keywords were "smart building", "intelligent building", "smart construction", "project management", and "project manager", combined as follows: smart building AND project management; intelligent building AND project management; smart construction AND project management; smart building AND project manager; intelligent building AND project manager; smart construction AND project manager. To select the articles that adhered to the research, the following inclusion criteria were adopted: (1) studies on intelligent buildings related to at least one of the ten areas of project management, according to [6] (scope, schedule, costs, quality, resources, communications, risk, procurement, stakeholders, and integration); (2) studies published in the last ten years, so that the content was the most representative of current reality. Figure 1 summarizes the article selection process.

Identifying smart buildings fields made it possible to analyze the researched areas, considering the vast scope of project management. The smart buildings fields were considered guidelines for elaborating the competencies necessary for a smart building project manager.

2.2. Identification of the Specificities That Influence the Management of Smart Building Projects

In the smart building field, the developmental context of the activities of a smart building project manager was analyzed. A smart building field general characterization enabled an analysis of integrated concepts between study areas, presenting the general context of smart building project management. In turn, the smart building field risks, scope, costs, schedule, technologies and systems, and sustainability presented by the

particularities of the respective areas were identified, characterizing the specific context of the project management of smart buildings. Next, the specificities of project management of smart buildings were grouped by smart building fields.

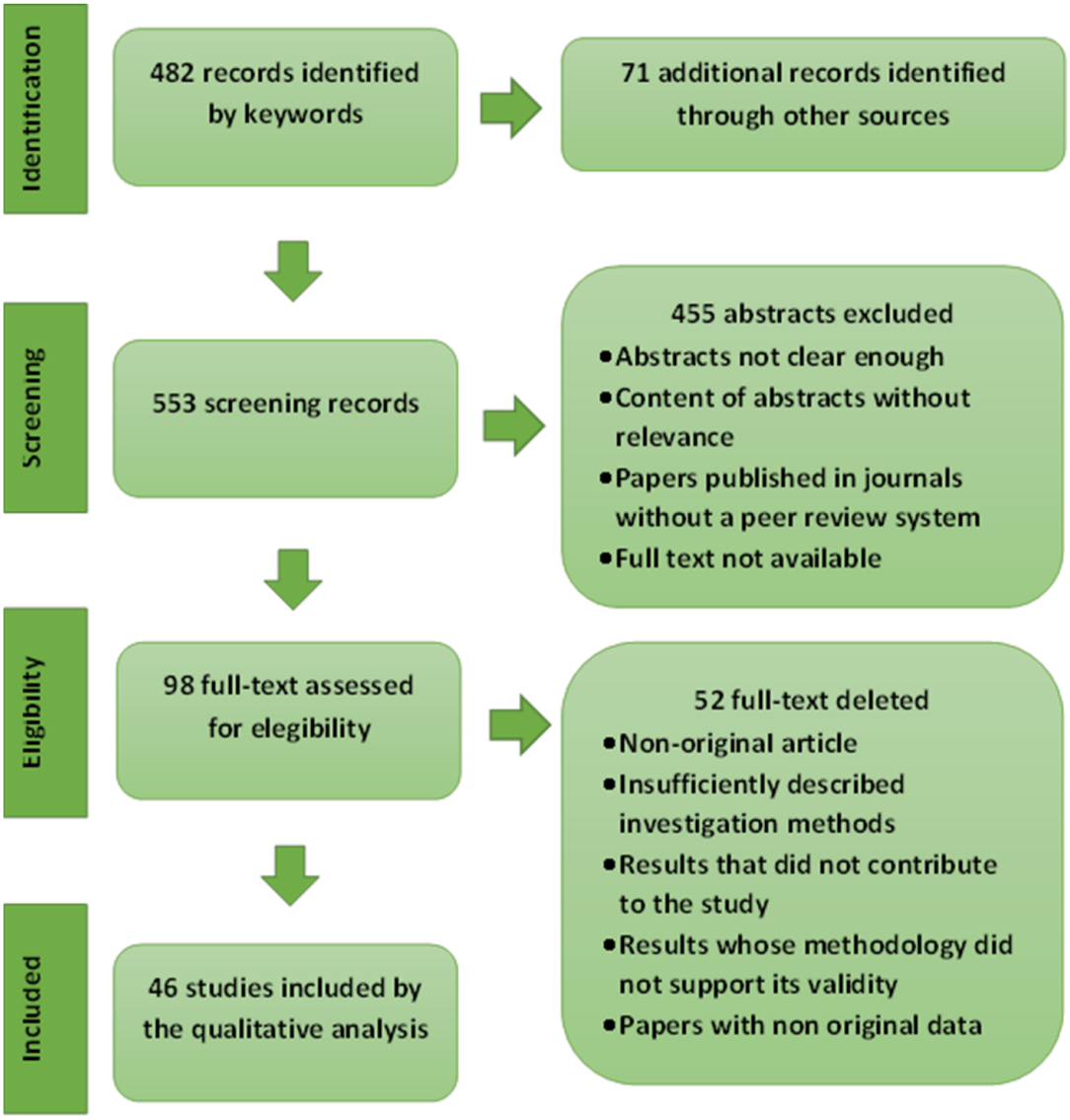


Figure 1. Synthesis of bibliographic research from a PRISMA flowchart.

2.3. Identification of Skills Needed by Smart Building Project Managers

To determine the specificities that influence the management of smart building projects, they were related to the competencies of project managers mentioned in the literature, to identify a set of more relevant competencies for project managers. It is essential to point out that, as with any project, the competencies related to project management available in the literature also apply to smart building projects to a greater or lesser extent. The specificities of each type of project can influence the importance given to each competence.

Identifying smart building fields made it possible to analyze the researched areas, considering the vast scope of project management. The smart building fields were considered guidelines for elaborating the competencies necessary for a smart buildings project manager.

3. Results and Discussion

Using the smart building fields as drivers, an overview of smart building project management was conducted, which made it possible to understand the specificities of

applying smart technology to buildings. Based on this panorama, the most relevant competencies for smart building project managers were identified.

3.1. Smart Building Fields

The data analysis started by identifying smart building fields and their respective research approaches. These can be tangible or intangible, directly or indirectly influencing the project, and involving the building or related elements. The seven smart building fields proposed in this research are general characterization, risks, scope, costs, schedule, technologies and systems, and sustainability.

Smart building fields have the potential to contribute to the management of smart building projects, due to the following aspects:

- Thematic scope: the proposed smart building fields address risks, scope, and technologies and systems (parts inherent to the smart buildings), as well as general approaches such as barriers and challenges to the project (general characterization);
- Targeted search: The smart building fields encompass the project management fields of smart buildings with a more significant recurrence in the researched literature based on the keywords used;
- Presentation of tools to manage the project: smart building field technologies and systems include tools such as building information modeling and the Internet of things. Risk management also has tools. These tools can be used in more than one phase of the project and support the activities of the smart building project manager;
- Smart buildings execution phases: smart building fields are applied in the three smart building execution phases considered in this research [9]: (1) the planning and design phase: general characterization, risks, and scope; (2) construction phase: costs, schedule, technologies and systems, and sustainability; and (3) operation and maintenance phase: general characterization. This grouping by execution phases considers the relationship of the specificities of smart building fields with the project's respective phases. This means that smart buildings fields are not necessarily restricted to just one phase. In addition, this emphasizes that the smart building fields are related to each other.

The aspects described above were considered for the use of smart buildings fields as drivers for characterizing the management of smart building projects. This list can be expanded as new smart building fields emerge in the literature.

Table 1 presents the seven proposed smart building fields, which were identified from the approaches of works related to the project management of smart buildings in the selected literature, allowing the identification of specificities. Studies that directly and indirectly addressed the management of smart building projects were included. Thus, Table 1 presents the seven smart building fields and the respective studies and research approaches consulted.

Table 1. Smart Building Fields.

Smart Buildings Fields	Approaches
General characterization	• Smart buildings (project and service value creation processes) [31]; • Intelligent buildings (design process) [3]; • BIM and intelligent buildings (nexus and challenges) [9]; • Internet of things and smart buildings (trends and challenges) [32]; • Smart building projects (risks and challenges) [33]; • Smart buildings (research of research) [5]; • Smart building technologies (barriers to project management processes) [13]; • Construction of intelligent buildings (influence of specific regulations) [11]; • Smart buildings (systems and drivers identification) [10];

Table 1. *Cont.*

Smart Buildings Fields	Approaches
Risks	• BIM and intelligent buildings (nexus and challenges) [9]; • Innovative, energy efficient, and sustainable building (risk management) [34]; • Intelligent buildings (risk control structure) [35]; • Intelligent buildings (risks of investment projects for construction) [36];
Scope	• Intelligent buildings (design process) [3]; • Smart buildings projects (challenges in Egypt) [33]; • Smart building (management system) [37]; • Smart buildings (research of research) [5]; • Construction of intelligent buildings (influence of specific regulations) [11];
Costs	• Smart buildings (research of research) [5]; • BIM and intelligent buildings (nexus and challenges) [9]; • Internet of things and smart buildings (trends and challenges) [32]; • Smart building technologies (barriers to project management processes) [13]; • Smart building technologies (barriers to project management) [12]; • Smart energy buildings (energy management) [38]; • Facility management of smart buildings (general aspects, facilities manager) [39];
Schedule	• BIM and intelligent buildings (nexus and challenges) [9]; • Smart building technologies (barriers to project management) [12];
Technologies and Systems	• Smart building (management system) [37]; • Smart energy buildings (energy management) [38]; • BIM and intelligent buildings (nexus and challenges) [9]; • Conventional buildings and smart buildings (building information modeling—facility management) [15]; • Smart buildings (adoption and functionality of the Internet of things) [40]; • Smart buildings (systems and drivers identification) [10];
Sustainability	• Smart energy buildings (energy management) [38]; • Smart buildings (tasks, scope, and innovations) [41]; • Smart buildings (energy saving and user activities) [42];

A general characterization of smart building fields considers objectives, barriers, challenges, and regulations. Smart buildings fields risks were identified from the risks related to the execution of smart building projects. The scope of smart building fields encompasses elements related to the scope of the project and/or the product. The smart building fields cost encompasses the costs of materials, equipment, and technologies. The smart building field schedule addresses information related to the project execution time, having a close relationship with the smart building field cost. Smart building field technologies and systems encompass the most significant systems mentioned in the surveys. Finally, smart building field sustainability covers, among other aspects, consumption and the need to reduce energy.

3.2. Specificitiess of Smart Building Project Management

The smart building fields directed the search for specificities of the smart building projects. The insights and findings related to these specificities could be related to each other. Table 2 presents these specificities aggregated by smart building fields and the main related competencies.

The project areas group the competencies as shown in Table 2 and may be required by one or more areas. The most expressive core of competencies is formed by the most mentioned competencies: leadership, technical competencies, and strategic competencies.

Leadership is one of the key competencies for project management and one of its main aspects is team management to achieve the organization's business goals [6]. In the case of smart building projects, there is a greater demand for professionals with skills that are normally not necessary for conventional buildings, such as those related to technology,

which increases the multidisciplinarity of teams that seek to meet many objectives, so that it is possible to achieve the main objective of the project; in this case, the delivery of smart buildings. In this context, leadership is a fundamental competence. In addition, organizing the relationship between stakeholders and ensuring collaboration between all parties involved is critical to the process of establishing smart buildings [31], which demands a leadership role.

Table 2. Project management specificities of smart buildings and project manager competencies aggregated by smart building fields.

Smart Building Field	Specificities that Influence the Management of Smart Building Projects	Main Competences
General Characterization	• "Integrated project management can be considered one of the most important characteristics of smart buildings" [33] • For a green smart building, specific project management skills are required at all stages; there is a need for standardized evaluation methods and tools for evaluating the requirements of smart buildings [43]; • For green smart buildings, there is a need for adequate knowledge of alternatives; general public awareness of socioeconomic and environmental benefits; training for stakeholders on technical and non-technical aspects [43]; • Construction of innovation structures is incorporated into the construction process of a smart buildings [44]; • The objectives of smart buildings include reducing pollution and improving occupant safety [31]; • The main target of smart buildings is to reduce energy consumption and the amount of CO_2 produced in the construction sectors [3]; • During the construction phase, the objectives of the smart buildings include the schedule, cost, safety, quality, and environment [9]; • Compared to traditional buildings, smart buildings have a high level of technical content, higher risks, and complex construction procedures [9]; • Smart buildings implementation challenges include cost, business models, security, and privacy [32]; • For smart buildings projects, the main challenges are "lack of experience in the field of SBP; absence of facility management team; lack of framework to establish SBP; high life cycle costs." [33]; • Barriers to the promotion and acceptance of smart buildings include lack of financial resources, confidence to undertake new and untested technologies, professional ability to incorporate and manage smart technologies, and knowledge of developers and owners [5]; • The most reported barriers to project management for the adoption of smart building technologies include the "lengthy approval process for new SBTs, structure, and organization of the construction industry, higher cost for smart construction practices and materials, unfamiliarity with smart building technology and technical difficulty during construction process" [13]; • Regulatory requirements can directly or indirectly affect the design of smart buildings [11]; • "There is no adequate incentive policy for designers and developers for supporting them to develop knowledge and methods for green smart building" [43]; • The main drivers of smart buildings are: technology; integration; flexibility; longevity; health; comfort; satisfaction; security; ecology; energy; efficiency [10];	• Technical competencies: demanded by the specificities of reducing consumption and emissions, technical content, and complex construction procedures; • Leadership: required mainly due to the multidisciplinary nature and specificities of a smart building project. Leadership is related to the management of multidisciplinary teams and the achievement of the multiple objectives of a smart building project; • Strategic management: demanded mainly by the challenges and barriers to the implementation of smart buildings (costs and business model; lack of financial resources); • Communication: just like leadership, this is demanded by the multidisciplinary approach and wide range of specificities contained in a smart building project, requiring effective communication for proper management of teams and the relationship with stakeholders;

Table 2. *Cont.*

Smart Building Field	Specificities that Influence the Management of Smart Building Projects	Main Competences
Risks	• Smart buildings have a high level of risk compared to traditional buildings [9]; • For risk management, in addition to qualitative and quantitative assessment, the specific nature of innovative projects should be considered, including a third parameter: the possibility of risk remedy [34]; • The system for risk management in the implementation of smart building projects includes three levels of risk management: top management level, specialized substructure level, and line management level [35]; • Risk assessment can be carried out with a focus on investment projects for the construction of intelligent buildings [36]; • Elevated risks in the final phase of the project can be an indication that risks were ignored or not identified in the initial phases of the project [33]; • In green smart buildings, information about the risk caused by new technologies is required [43];	• Attitudes towards risk: demanded mainly by the high-risk level of smart buildings and the risks identified in the final phase of the project; • Specifying real requirements: demanded by the need to identify risks in the initial stage, information about the risk of new technologies, and risk analysis for innovative projects; • Technical competencies: demanded by the need to carry out risk analyses;
Scope	• Intelligent buildings do not have a consensual definition [3]; • Most definitions point to meeting user needs [33]; • The design and development of intelligent buildings require deep insights into control theory, machine learning, system specifications, and design requirements [37]; • Intelligent buildings must have advanced automatic control systems to monitor various facilities, good networking infrastructure to enable data flow between floors, and adequate telecommunication facilities [5] • Regulatory requirements can promote the design of smart buildings [11];	• Technical competencies: mainly required by the elaboration of the building project, where it is necessary to consider the concepts of SBs and a strong technological influence; • Leadership: defining the scope of the SBs project requires consultation with different stakeholders and the ability to manage different demands;
Costs	• Compared to a traditional building, the construction costs of a smart building are higher [5]; • The high demand for materials, equipment, and technical personnel causes an increase in construction costs [9]; • Internet of things solutions can increase costs for buildings [32]; • High costs for smart practices and equipment are one of the biggest barriers to the project management process for the adoption of smart building technologies [13]; • The main barrier to the adoption of smart building technologies in developing countries is the high cost of materials and equipment [12]; • To reduce costs, engineers and researchers seek to optimize systems, being able to maximize production, efficiency, profit, and performance [38]; • BIM allows managers to calculate the quantity and cost of materials [9]; • Smart building owners' preferences include minimizing acquisition, operating, energy, repair, and maintenance costs; and maximizing returns on investment and the level of building security and investment protection [39]; • For the technical implementation of a green smart building, the establishment, maintenance, and operation costs represent a challenge [43]; • "The construction cost-saving integrated systems are primarily attributable to the efficiencies in cabling, cable pathways, labor, project management, and system management hardware and software" [44];	• Budgeting and attitudes towards risk: mainly demanded because the costs of smart buildings are higher (emphasis on materials and equipment, as well as the need for staff training in new technologies); • Technical competencies: required due to the need to operate technologies (BIM, for example);
Schedule	• Schedule targets and smart building costs are closely related, being analyzed together in the literature [9]; • Project construction time can be reduced by using BIM [9]; • The adoption of smart building technologies in developing countries has as one of its latent barriers related to time [12];	• Budgeting, attitudes towards risk, and technical competencies: schedule and costs are intrinsically related; thus, for schedule, the same competencies related to smart building field costs apply;

Table 2. *Cont.*

Smart Building Field	Specificities that Influence the Management of Smart Building Projects	Main Competences
Technologies and Systems	• The development of an intelligent building management system is achieved by understanding all the project requirements and with consideration of the systems [37]; • Occupant behavior, activities, and preferences are important feedback for building automation [38]; • The systems are characterized by having a focus on building management, improving energy efficiency, and considering all aspects of design, performance requirements, and specifications of the smart buildings [37]; • BIM technology applications are necessary for the development of intelligent buildings and can be applied to schedule, cost, energy, and facilities management [9]; • BIM contributes to transforming a traditional building into an intelligent and sustainable building [15]; • The benefits of using BIM include cost reduction, construction time, and improvements in project quality [9]; • Smart building systems increase design efficiency and can reduce costs [44]; • The central idea of the Internet of things is the connection of people, systems, and environment at any time and place, which may become the main flow for the development of intelligent buildings [40]; • In addition to contributing to the building's operation phase, the Internet of things can contribute to the construction phase [40]; • The central systems of smart buildings are heating, ventilation, and air conditioning system (HVAC); light system; energy system; security system; telecommunications system; fire prevention and fighting system; vertical transportation system; hydraulic system [10]; • The digital transformation of the construction industry includes the use of digital twins, which are "digital models related to either an existing, on-going, or future construction project created and linked throughout its lifecycle"; their use interconnects with other technologies such as sensors and the Internet of things [45].	• Technical Competencies: demanded by the specificity of the use of technologies and systems in smart buildings (BIM, Internet of things, constructive systems identified by [22]; • Leadership: demanded by the need for integration between systems, phases, and project teams; • Communication: demanded by the management needs of the systems and technology implantation and operation teams.
Sustainability	• The energy efficiency of intelligent buildings and environmental comfort have been a matter of interest for most developed and developing countries [38]; • Energy-related intelligence in buildings comprises the ability of the building to interact with its users, manage energy consumption, and interact with the broader energy environment [41]; • User activities and behaviors impact energy consumption, making it necessary for energy-smart buildings to recognize occupant activities and adapt to save energy [42]; • Continuous monitoring of energy use in buildings can be performed through a wireless sensor network [42]; • Intelligent building systems collaborate to reduce the consumption of natural resources, emissions, and waste; benefiting sustainability and serving the interests of owners, investors, and users [10]; • The fundamental principles of building rehabilitation in the EU by 2030 and 2050 include energy efficiency, affordability, decarbonization and integration of renewables, lifecycle thinking and circularity, high health and environmental standards, tackling the twin challenges of the green and digital transitions together, and respect for aesthetics and architectural quality [46];	• Leadership: demanded by the need to serve different stakeholders (users, government, owner, among others); • Technical Competencies: demanded by the need for the integrated use of technologies to meet environmental requirements; • Organization: demanded by the number of new requirements to be met;

Leadership is directly related to the achievement of organizational goals [6]. In turn, the organization's goals are directly related to strategic planning. Therefore, there is a relationship between leadership and strategic management competencies, indicating that these competencies can be jointly demanded from project managers. Another example is the

schedule and cost targets of smart buildings, which are analyzed together in the literature [6] and include, as the competences indicated in Table 2, knowledge of budgeting and risk skills, which also shows that competencies are demanded and integrated throughout a project. Thus, the relationship is observed between competencies that, even though areas in Table 2 group them, are demanded in an integrated manner throughout an entire project, to a greater or lesser extent.

Concerning the strategic management competency, project management of smart buildings occurs in an environment subject to change and strongly influenced by technological innovations, which requires project managers to align with organizational objectives to succeed in delivering the project. This competence supports the project manager in his relationship with the organization of which the project is part, it being necessary to "implement decisions and actions that support the strategic alignment and innovation" [6]. The dynamism contained in the smart building projects, whether due to the constant evolution of the concept [3] or due to challenges faced such as costs, business model, security and privacy [32], or even the amount of technology available for application in smart buildings, indicates that managers of projects must be aligned with the organizational strategy, so that they can be included in the project elements that contribute to the achievement of organizational goals and, therefore, the success of the project.

Technical competencies also form a significant part in the composition of Table 2. According to [26], technical competencies include experience, authority, and technical knowledge, thus relating to the development of a smart building project, which considers factors such as the high-level technical content of the project, the presence of complex construction procedures [9], and the need to include recent technologies with which there is little or no application experience [5,33]. In addition, smart building design has a wide range of systems and technologies in constant development, as seen in smart building field technologies and systems (Table 2). Consider also that smart buildings are civil construction projects, where there is a strong influence from technical requirements. Under these aspects, it is observed that technical competencies will be demanded recurrently throughout the entire project.

Another important point is the definition of the scope of smart buildings. As previously seen, smart buildings do not have a consensual definition [3], which impacts the scope of smart buildings. The conceptualizations identified in the literature bring a set of requirements and elements that must be considered [2]; allied to this is the need for alignment with the organizational strategy, so that the project delivered can meet the result expected by the organization. In this context, the project manager will be asked to specify project requirements in a clear, objective, and assertive manner, justifying the presence of the competence specifying real requirements in Table 2. Managers should consider, for example, the requirements and elements proposed in the concepts of smart buildings [2] and the objectives and targets that smart buildings seek to achieve [3,31]. This complex task is interconnected with other skills, such as communication and leadership (because it requires the management of multidisciplinary teams).

Smart buildings' most significant project risks also demand greater attention concerning risk-related competencies. The most significant risks are related, for example, to higher costs for materials and equipment and the use of new or untested technologies [5], as seen in innovative projects that require a risk assessment with more parameters [34]. The risk assessment of the investment made to construct smart buildings [36] should also be considered, which can be more complex. Thus, concerning smart building field risks, project managers are required to have skills that enable them to assertively define the scope of the project (specifying real requirements), understand the project properly (project knowledge management), act in case of risk (attitudes towards risk) and appropriately lead the team, and minimizing risks in an innovative project (leadership). These skills require the manager to have in-depth knowledge of the project, to anticipate risks that may impact the project.

Communication is also an essential competence for project managers of smart buildings since there is a tendency for teams to be more multidisciplinary, and the specificities of smart buildings demand a more significant number of changes to the project, implying the need to communicate these changes. In addition, in the developmental environment of innovative projects, as is the case of smart buildings, the importance of good communication is known, given the need to implement little-known technologies [5].

Organizational competence was also considered essential, mainly because the characteristics and specificities of smart building projects make the number of requirements to be met greater than that of conventional buildings, demanding greater capacity from the project manager to structure his activities and create standards and procedures.

When analyzing the skills required of smart building project managers, it is possible to observe the existing complementarity between hard and soft skills. Although a smart building project requires in-depth technical knowledge, it is also observed that managers need soft skills such as communication and leadership. This existing relationship strengthens the list of competencies, by expanding the scope of competencies and not being restricted to technical competencies.

This work contributes to the existing literature on project management by identifying the main competencies required of smart building project managers from the traditional range of competencies and collaborating to reduce the extensive lists of competencies associated with project success. It also contributes to the literature on smart buildings by identifying important research fields and specificities of smart building projects.

Concerning practical implications, this work shows that project managers need to incorporate knowledge and skills that make them capable of acting in a multidisciplinary environment, with rapid changes and strongly influenced by technological innovations. This environment means that smart building projects have specificities that demand a more significant focus on certain skills from project managers. In addition, by highlighting the specificities of smart building projects, this work contributes to project managers acquiring knowledge about them, supporting their activities, and contributing to project success.

The findings also have implications for the education and training of project managers, since the specificities of smart building projects may require new knowledge. In the literature, the need to adjust the gap between education and the real world of project management has been reported as fundamental [26]

Bearing in mind that smart buildings are an increasingly present reality worldwide, we expect that this work will contribute to improving the activities of smart building project managers and, consequently, to the success of projects.

4. Conclusions

The research question of this study was "In the context of numerous and extensive lists of competencies proposed for project managers in the literature, is it possible to identify a set of competencies that are most relevant for project managers of smart buildings?". The hypothesis investigated was that the specificities of intelligent building project management make some competencies more important for managers of this type of project.

After a broad and detailed literature review, the main research fields related to the management of smart building projects and the specificities of these fields and that can influence the management of this type of project were identified. These specificities were related to the competencies of project managers mentioned in the literature, to identify competencies that may be more relevant for the project managers of smart building projects.

The findings showed that the specificities of smart building project management make some competencies more critical. Thus, project managers should focus on nine competencies: technical competencies, leadership, communication, budgeting, attitudes toward risk, strategic management, organization, and specifying real requirements. However, it is important to highlight that the competencies related to project management available in the literature also apply to smart building projects to a greater or lesser extent.

The main research fields are scope, risks, costs, schedule, technologies and systems, sustainability, and general characterization, which consider objectives, barriers, challenges, and regulations.

The project manager concept adopted in this work has some limitations. Concerning the relationship with the performing organization, the concept adopted only considers what is presented in the PMBOK as "strategic and business management skills", focusing on the business model. Within the scope of this work, this means having knowledge and information about the organization that makes it possible to align the project with the company's strategies, mission, goals, and objectives. With regard specifically to the project, the project manager must have competencies that make him capable of working on the project's particularities from the perspective of the knowledge areas of project management. Regarding the project manager's responsibility, we delimit his association with the project's success; that is, he is responsible for making the project achieve the planned results using the metrics established for each knowledge area of project management, in accordance with the organizational strategies, goals, and objectives.

Considering that the research fields and specificities of smart building projects were identified from bibliographical research, this study is subject to the typical limitations of research based on a literature review, as there is always the possibility that a significant article was not identified.

Regarding future studies, given the environmental dynamism in which intelligent buildings are developed, other competencies could be identified and added to the list. Competency lists could also be deepened for specific management areas, such as the field of technologies and systems. Another possibility of study would be analyzing how competencies can impact a project's expected results for traditional buildings compared to smart buildings. In addition, the relationship between hard and soft skills for the results of smart building projects could be analyzed. Finally, surveys could be carried out with professionals in the field, to prioritize the competencies required for managing smart building projects.

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