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IJISPM

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Mission

The mission of the IJISPM - International Journal of Information Systems and Project Management - is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

The IJISPM publishes leading scholarly and practical research articles that aim to advance the information systems management and project management fields of knowledge, featuring state-of-the-art research, theories, approaches, methodologies, techniques, and applications.

The journal serves academics, practitioners, chief information officers, project managers, consultants, and senior executives of organizations, establishing an effective communication channel between them.

Description

The IJISPM offers wide-ranging and comprehensive coverage of all aspects of information systems management and project management, seeking contributions that build on established lines of work, as well as on new research streams. Particularly pursuing multidisciplinary and interdisciplinary perspectives, and focusing on currently emerging issues, the journal welcomes both pure and applied research that impacts theory and practice.

The journal content provides relevant information to researchers, practitioners, and organizations, and includes original qualitative or qualitative articles, as well as purely conceptual or theoretical articles. Due to the integrative and interdisciplinary nature of information systems and project management, the journal may publish articles from a number of other disciplines, including strategic management, psychology, organizational behavior, sociology, economics, among others. Articles are selected for publication based on their relevance, rigor, clarity, novelty, and contribution to further development and research.

Authors are encouraged to submit articles on information technology governance, information systems planning, information systems design and implementation, information technology outsourcing, project environment, project management life-cycle, project management knowledge areas, criteria and factors for success, social aspects, chief information officer role, chief information officer skills, project manager role, project manager skills, among others.

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- project environment
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- managing organization - responsibilities
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Correspondence and questions

All correspondence and questions should be directed to João Varajão (Editor-in-Chief). E-mail: editor.ijispm@sciencesphere.org

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Editorial

The mission of the *IJISPM - International Journal of Information Systems and Project Management* is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

It is our great pleasure to bring you the fourth number of the ninth volume of IJISPM. In this issue, readers will find important contributions on project management and Building Information Modelling.

The title of the first article is “Risk and vulnerability management, project agility and resilience: a comparative analysis,” which is authored by Khalil Rahi, Mario Bourgault, and Christopher Preece. The main objective of this article is to present a critical analysis of the project management literature on four concepts: risk management, vulnerability management, project agility, and project resilience. The goal is to understand the strengths and weaknesses of these concepts to deal with disruptive events through the development of a conceptual framework that captures their differences and convergences. Therefore, a review of recent literature from international journals, specialized mainly in project risk management, vulnerability management, project agility, and project resilience, has been conducted. Results from this study show that risk management and vulnerability management are proactive concepts focusing on the management of known events or actions. Alternatively, project agility is a reactive concept that aims to adapt to changes but not necessarily disruptive events. Project resilience is a mix – proactive and reactive – focusing on recovering from known and unknown disruptive events.

The second article, authored by Canser Bilir and Yafez Elif, is entitled “Project success/failure rates in Turkey”. In the study, the success rate of projects in Turkey is measured, and the significant factors behind the successes and the failures of those projects are ranked. The applied methodology is adapted from the Chaos Report by Standish Group. The results showed that 48% of projects are completed successfully while 45% are eventually completed but either over budget, not on time, or not fully completed. The success rate of the reviewed projects is higher than the rate reported in the Chaos Report. However, the success rate of projects drops to 44% when only technology-driven projects are considered. As the project size increases, the success rate diminishes, as also demonstrated in the Chaos Report. The study on the significant factors influencing the success or failure of the projects revealed that the most critical factors are the “requirement definitions,” “requirement planning,” and “top management support.”

“Implementation of Building Information Modelling in infrastructure construction projects: a study of dimensions and strategies” is the third article and is authored by Mahmoud Ershadi, Marcus Jefferies, Peter Davis, and Mohammad Mojtahedi. The emergence of Building Information Modelling (BIM) has revolutionized the infrastructure construction industry by introducing real-time and collaborative information management tools to be used throughout the lifecycle of projects. The importance of BIM in this industry has been emphasized in previous research. However, strategies for the implementation of this system is still less explored, which requires more elaboration and validation. The purpose of this article is to investigate such strategies considering all necessary dimensions of the BIM system in infrastructure construction projects. The results revealed that BIM integrates various elements of infrastructure construction, which include but are not limited to risk, time, cost, energy, safety, and sustainability. It was found that implementation strategies should focus on improving the contribution of the BIM system to infrastructure construction in terms of improved (1) integrity and automation, (2) collaboration, and (3) optimization. Identification of seven technical and managerial implementations strategies is the core contribution of this research. These strategies provide practitioners with insight into technical and managerial measures to be taken for the successful implementation of the BIM system.

The fourth article, “Information systems project management success”, is authored by João Varajão, António Trigo, José Luís Pereira, and Isabel Moura. The purpose of the article is to give new insights into the success of information

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systems (IS) project management. Even though many studies found in the literature show results of software development projects, few studies address the success of IS (socio-technical) projects. Responses to an international survey, representing 472 projects in total, showed that IS project management is achieving high levels of success; yet, only a minority of projects end without changes in scope, time, or cost. Furthermore, results show that changes in scope, time, or cost are frequent in this kind of project and do not significantly affect the perception of success. These results provide researchers and practitioners with a better understanding of IS project management success evaluation.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

The Guest Editor,

Ricardo Martinho

Polytechnic Institute of Leiria

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Ricardo Martinho is an Associate Professor at Polytechnic of Leiria, Portugal. He teaches several subjects related to enterprise information systems, enterprise application development, software engineering (agile methods) and healthcare computer programming and information systems. He graduated in Electrical Engineering - Computer Science at University of Coimbra, received his MSc in Computer Science - Information Systems Programming from IST - Technical University of Lisbon, and his PhD from University of Trás-os-Montes and Alto Douro. He is also a Researcher at the Center for Health Technology and Services Research (CINTESIS), and at INESC Coimbra. He has more than 90 publications in journals, books and conference proceedings related to Software Engineering, Business Process Management, Process Mining and Health Informatics. He serves as executive editor, member of editorial board and reviewer for several books and international journals, and has served in several committees of international conferences. He is a co-founder of HCist - International Conference on Health and Social Care Information Systems and Technologies (http://hcist.scika.org).

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Risk and vulnerability management, project agility and resilience: a comparative analysis

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Risk and vulnerability management, project agility and resilience: a comparative analysis

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Abstract:
The main objective of this paper is to present a critical analysis of the project management literature on four concepts; risk management, vulnerability management, project agility and project resilience. The goal is to understand the strengths and weaknesses of these concepts to deal with disruptive events through the development of a conceptual framework that captures their differences and convergences. Therefore, a review of recent literature from international journals, specialized mainly in project risk management, vulnerability management, project agility, and project resilience has been conducted. A systematic literature review is adopted to compare the four key concepts of this study and to draw conclusions. A case from the information technology field is used to better illustrate the comparison. Results from this study show that risk management and vulnerability management are proactive concepts focusing on the management of known events or actions. Alternatively, project agility is a reactive concept that aims to adapt to changes, but not necessarily disruptive events. Project resilience is a mix concept – proactive and reactive – focusing on recovering from known and unknown disruptive events. In addition, this comparative analysis and the conceptual framework developed can be used to exploit future areas of research and exhibit new opportunities where project management best practices can be improved to deal with disruptive events.

Keywords:
risk management; vulnerability management; project agility; project resilience; critical analysis.

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1. Introduction

Projects are temporary organizations in which human and non-human resources are utilized to achieve specific goals [1]–[3]. Their management always represents a challenge "*since it interacts with time pressures and uncertainty of the results due to the fact that the project completion is something new or/and revolutionary, involves transient teams, and has risks*" [4, p. 29]. It is a challenge because projects are on a regular basis confronted to disruptive events that, on occurrence, can cause severe deviations from the project main objectives [5], [6]. Therefore, it becomes a necessity, in project management, to deal effectively with these events through the development of new methods, tools and best practices [7]. In fact, as mentioned by Thamhain [8], project leaders must go beyond the mechanisms of examining the task and its contractual components of the "triple constraint," such as cost, schedules, and deliverables, to investigate and understand the sources of uncertainty before attempting to control them [8].

In this paper four topics are discussed that aim to deal with disruptive events during the project life-cycle. These events can lead the project to deviate from its main objectives (e.g., become delayed, run over budget, produce low quality, incomplete the scope, incur client dissatisfaction, etc.) [5]. The first topic is risk management that intends to manage possible future disruptive events through their identification, analysis, and mitigation during the project life-cycle [8], [9]. The second topic is vulnerability management that addresses the management of the project's characteristic that makes it susceptible to disruptive events [10], [11]. The third topic is project agility that is related to the capacity of the project team to quickly modify the project plans when faced with changes (i.e. disruptive events) [12]. Finally, the fourth concept is project resilience that correlate with the project's ability to be aware of and adapt when faced with disruptive events [6]. Therefore, the main subject that relates these four concepts is the management of disruptive events. Thus, analyzing these four concepts will allow the understanding of their strengths and weaknesses, and instigate the development of novel processes, tools and best practices to efficiently and effectively manage disruptive events during the project life-cycle.

The scope of this literature review was limited to scientific journals that covers risk management, vulnerability management and project agility in the project management field specifically. However, white papers and other popular media are considered when reviewing the concept of project resilience due to the novelty of the project resilience concept and the lack of scientific literature on this concept [7], [13]. It is also to mention that this review is mainly achieved through analysis of recent literature on these four concepts. Mainly because the main objective is to find new areas of opportunities for advanced development of new methods, tools and best practices.

That being said, this paper is organized in three distinct sections. In the first section, the methodology of the systematic literature review is explained. In the second section, the four main concepts of this study are explored independently to better understand their strengths and weaknesses. In the third section, a critical analysis of the literature on these four concepts is conducted to explore scientific areas of opportunities. This analysis is supported through a case of the implementation of Information Technology (IT) projects to better illustrate the main ideas. In addition, a conceptual framework linking these four concepts is also proposed to open the door for future research on new tools, methods and best practices to effectively and efficiently deal with disruptive events during the projects' life-cycles.

2. Methodology

This paper aims to develop a clear understanding of the strengths and weaknesses of four concepts that aim to deal with disruptive events. After a thorough analysis of the literature on these concepts, a conceptual framework is developed through the theory building approach to develop relationships and draw academic conclusions for future research [14], [15].

In addition, a case from the information technology field is used to better illustrate the relationships between these concepts. This aims to provide a real-world context in which the management of disruptive events occurs [16].

The proposition of conceptual frameworks to compare between concepts follows the same process that has been used by many authors (e.g., the works of [17]–[19]). As discussed by Burnard and Bhamra [20], "*conceptual frameworks aid in not only providing construct validity, but also provide an outline for future research activities*" [20, p. 5585].

The literature review aims to identify key elements of risk management, agility, vulnerability and resilience directly related to the field of project management. Therefore, a search of the literature in databases that deal specifically with research in management and science of organizations was conducted. Databases included Google Scholar, Web of Science, ProQuest, etc. The following keywords were used to complete the search: "concept", "resilience*", "agil*", "risk management", "project management", "vulnerability*". The main objective was to choose scientific documents (journal articles, thesis and dissertations), in the English language, that link two or more concepts (risk management, vulnerability, agility, resilience) to the project management field.

It is worth to mention that some concepts are widely used in the project management literature without referencing to their respective concept. These were excluded from this study. For instance, the word "agile" or "agility" is commonly used in project management, mainly in the IT sector. However, the literature on the concept of "agility", as a scientific progression, is not well defined and developed. Our goal was to identify the concepts not the words, such as "agile", "vulnerable", "risky", that are deployed in their general context.

So, a total of 18742 scientific documents were found in the first step of the literature search. After an examination of titles and abstracts, 18503 articles were eliminated because they did not focus on the main objective of the study. Eleven more articles were eliminated because they were duplicates. A review of the full-text formats of the remaining 228 publications resulted in the exclusion of another 192 scientific documents. Finally, a total of 36 studies were considered in the review (**Table 1**). The screening process for publications obtained from searches is depicted in **Figure 1**.

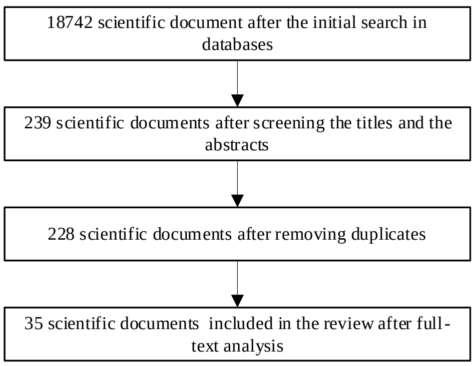

Fig. 1 – Screening process of scientific documents

Table 1: final list of scientific documents chosen for this review

Authors of Article/Thesis	Risk management	Resilience	Agility	Vulnerability	Field or research/Type of projects
(Huchzermeier & Loch, 2001)	√		√		Research and development
(Ward & Chapman, 2003)	√	√			General perspective
(Kutsch & Hall, 2005)	√	√			Information technology
(Coram & Bohner, 2005)	√		√		Information technology
(Taylor, 2006)	√		√		Information technology
(Ahmed et al., 2007)	√				Product development

Authors of Article/Thesis	Risk management	Resilience	Agility	Vulnerability	Field or research/Type of projects
(Zhang, 2007)	√			√	General perspective
(Nelson et al., 2008)	√		√		Information technology
(Sanchez et al., 2009)	√			√	General perspective
(Lee & Yong, 2010)	√		√		Information technology
(Geambasu, 2011)	√	√			Construction
(Zhang, 2011)	√			√	General perspective
(Vidal & Marle, 2012)	√			√	General perspective
(Besner & Hobbs, 2012)	√		√		General perspective
(Besner & Hobbs, 2012b)	√		√		General perspective
(Schroeder & Hatton, 2012)	√	√			Research and development
(Thamhain, 2013)	√				Product development
(Tomanek & Juricek, 2015)	√		√		Information technology
(Baweja & Venugopalan, 2015)			√		General perspective
(Turner & Kutsch, 2015)	√	√			General perspective
(Thomé et al., 2016)	√	√	√		General perspective
(Conforto et al., 2016)			√		General perspective
(Lehnen et al., 2016)	√		√		Product development
(Zhu, 2016)	√	√		√	Construction
(Blay, 2017)	√	√		√	Construction
(Aleksic et al., 2017)				√	General perspective
(Hobbs & Petit, 2017)	√		√		Large projects in large organizations
(Mochizuki et al., 2018)	√	√			General perspective
(Rahi, 2019)	√	√			General perspective
(Rahi et al., 2019)	√	√			Information technology
(Wang, 2019)	√			√	General perspective
(Naderpajouh et al., 2020)	√	√			General perspective
(Tam et al., 2020)	√		√		Information technology
(Bianchi et al., 2020)	√		√		Information technology
(Varajão et al., 2021)		√	√		Information systems
(Varajão & Amaral, 2021)	√		√		Information systems

3. Risk Management

Risks are possible future events that may or may not occur (they have a certain probability). If they do occur, they will have negative (threats, adverse effects) or positive (opportunities) consequences for a project's endeavors [21]–[23]. Therefore, from a project management perspective, the main objective of risk management is to diminish the gravity of possible negative disruptive events in order to achieve the project objectives [21], [24].

The management of these disruptive events can be classified into two categories. The first category perceives the project as a system with clear and precise objectives, free from stakeholders' perceptions. Consequently, systematic and rational risk management processes and methods are adopted to deal with the logical and objective consequences of risks (e.g., the works of Baccarini [25]; Huchzermeier and Loch [26]; Williams and Thompson [27], etc.). The second category considers the management of these disruptive events to depend on individual perception. In other words, different individuals can have different perceptions on how to manage them. These ways are often based on the individual's personal experience, skills and expertise, along with psychological and organizational factors [11], [23]. One of the most important methods of dealing with these disruptive events is the method proposed by Ward and Chapman [23], who focus on managing uncertainty because managing perceived dangers, opportunities, and their consequences is not the only aspect of uncertainty management. It is about understanding and controlling all of the various sources of uncertainty that influence and affect perceptions of dangers and opportunities [23].

Additionally, challenges with the management of disruptive events from a risk management perspective is that individuals identify risks based on their perceptions and put in place policies to manage these risks. Moreover, different people with different emotional and moral reactions may identify different disruptive events and put in place different strategies to manage them. Therefore, the interaction between events, circumstances, and individual reactions contribute to the identification and analysis of risks [28]. This perspective is also discussed by Kutsch and Hall [29], who find that project stakeholders do not identify risks rationally because they intentionally or unintentionally tend to ignore, deny or avoid risks. These acts (ignoring, denying, avoiding) are associated with environmental conditions that affect stakeholders' judgment of risks, the effectiveness of risk mitigation plans, and their impact on the project's objectives [29].

From this perspective, the consequences of possible future disruptive events are extended to include secondary impacts such as shame, fairness, justice, etc. These secondary effects might be thought of as subjective overlays placed by persons who are confronted with external phenomena [28]. Therefore, the analysis of this type of risk aims to understand the discernment and cultural identity of risks by reinforcing the strength of economic, social, and technological systems [30].

There are a variety of strategies, processes, methodologies, and approaches for assessing and managing project risks, however it is unclear if they are effective or necessary for project management success [31]–[33]. De Bakker et al. [32], for example, attempted to explore the relationship between risk management and the success of IT initiatives. They concluded that neither the evaluation technique nor the management strategy, regardless of the setting in which the project is conducted, has led to conclusive evidence about the relationship between risk management and IT project success. In reality, they concluded that empirical data is primarily anecdotal and focused on how risk management is intended to operate rather than how it is really employed in project practice [32]. Furthermore, there have been instances when project managers did not use risk management strategies yet the project still succeeded, whereas other managers used risk management methods but their projects failed [32], [34]. In other words, while projects continue to fail in some cases, it is unclear whether the problem stems from ineffective risk management procedures or from project managers' ineffective application of risk management practices [34]. Researchers have also discovered that most project managers do not follow risk management practices as thoroughly as project management organizations and risk management standards recommend [31], [32]. This was also observed by Taylor [35], who indicated that project managers do not analyze future possible disruptive events by applying the traditional methods. They use three main strategies to deal with risks: control and monitoring, negotiation, and research. He argues that this tendency can be perceived from two points of view: *"(a) the extent to which IT project managers do not adhere to formal risk management prescriptions, and (b) the inability of the formal prescriptions to provide practical guidance in the situations faced by project managers*" [35, p. 61].

Besner and Hobbs [36] empirically identify a toolset for risk management composed of five tools to deal with disruptive events; risk management documents, positioning of risks, contingency plans, ownership of risk, and visualization of risk information. They noticed that the level of use of these tools is close to average which can be elucidated by the series of risk management actions. For instance, prior to rating risks and arranging contingencies, risk identification and documentation are required. In addition, they noticed a tendency to use less arduously complex tasks such as assigning owners to specific risks, and graphically presenting risk information [36]. These tools are used to better address specific organizational contexts and management problems. For instance, contexts such as large projects, important novelty, significant amount of resources, and high level of uncertainty, require a detailed risk management process. In addition, these risk management tools are needed in all the stages of the project life-cycle, more especially at the beginning of the project, to mainly address high levels of uncertainty. Besides, risk management tools are used in specific contexts (e.g., pharmaceutical industry), because they are simply an important requirement to approve the project plan.

In addition, these authors highlighted that the relationship between the management of risks and project success still not clear. Many risk professionals emphasized that despite the great visibility and positive view of risk management in their businesses, there is a significant gap between interest in risk management and resource allocation and staff training; many people talk about risk, but few do something about it [31]. Therefore, after reviewing the literature on the relationships between risk, risk management, uncertainty, and the context in which the projects are carried out, Besner and Hobbs [31] discussed the scope of risk management usage in relation to the degree of project uncertainty. Their study was completed through a quantitative analysis among 1296 experienced practitioners [31]. Logically, they were supposed to get results where risk management should be used extensively when managing highly uncertain projects, because risk management processes are supposed to improve project performance. However, an interesting paradoxical fact discovered by these authors is that risk management methods are often used when the project is well defined, and uncertainty is at its lowest level. Conversely, the higher the uncertainty, the less risk management is adopted. Thus, for well-defined projects, it is easy to realize that project analysis, planning, control, estimation, or evaluation are easier to do and thus done more frequently [31]. This fact is the reason why risk management tools do not give the desired results, because these tools are mainly applied on well-defined projects and used to manage well-known possible disruptive events. In addition, their analysis suggests that other, more flexible, practices are needed to deal with unexpected disruptive events because actual risk management practices are not appropriate for this type of events.

Despite these facts, approaches to deal with risks mainly include processes to identify risks, plan responses and control risks throughout the project life-cycle [21]. As concluded by Blay the failure to effectively handle shock, create capacities, and assure overall project recovery is a problem with these approaches. This is because the methods emphasize improving the project's ability to forecast a threat or an opportunity in order to handle them and avoid being surprised without emphasizing adaptability actions to recover from negative consequences [5].

4. Vulnerability Management

The concept of vulnerability emerged from social science and it is applied to economics, information systems, organizational management, politics, project management, etc. [11], [37], [38]. The main objective of vulnerability management is to deal with the weaknesses in the system's (e.g., the project) characteristics to avoid facing possible future disruptive events [11]. It is defined as "*the characteristic of a project which makes it susceptible to be subject to negative events and, if occurring, which makes it non-capable of coping with them, which may in the end allow them to degrade the project values*" [10, p. 10].

Füssel and Klein [37] distinguished among three main models for conceptualizing and defining vulnerability: (1) the "risk-hazard framework," where vulnerability represents the relationship between hazard and its adverse effects on a system; (2) the "social constructivist framework," where vulnerability is a prior condition of a system determined by socio-economic and political factors; and (3) a school of thought that considers vulnerability as a system function represented by the degree to which this system is susceptible to, or unable to address, the negative consequences of disturbances [37].

Inspired by the third school of thought presented by Füssel and Klein, from the project management perspective, Zhang [11] discusses vulnerability as a redefinition of the project risks process. He illustrates two dimensions that represent a project's vulnerability: exposure and capacity. The first dimension denotes the influence of organizational activities in the creation of disruptive events. The second dimension means that the higher the project's capacity to deal with disruptive events is, the lower its vulnerability will be. The notion of vulnerability can cause a project to better mediate disruptive events. In fact, to improve his process ability to explain and clarify, the nested interactions and feedback between risk occurrences and project systems are eliminated [11].

Vulnerability is defined as the characteristic of a project that makes it susceptible to disruptive events [10], [11]. Therefore, the existence of vulnerabilities is independent of the presence of disruptive events. For instance, within a project, not having the right qualified human resources to work on a specific task is considered a vulnerability. This vulnerability may (or may not) lead to poor-quality work. Therefore, a disruptive event ("poor-quality work") can be caused by a vulnerability ("not having a qualified person"), but a vulnerability does not necessarily lead to a disruptive event. In other words, the lower the vulnerability, the less likely it is that disruptive events will occur during the project life-cycle. Conversely, the higher the vulnerability, the more exposed the project is to disruptive events that may lead to its failure [11], [39].

Vidal and Marle [10] reviewed the literature on the concept of vulnerability in many scientific domains and proposed a project vulnerability management process composed of four steps (which are very similar to the phases of the project risk management presented in the previous section): the identification of project vulnerabilities, their analysis, the preparation of response plans to tackle them, and the processes of monitoring and controlling them [10]. Vidal and Marle's perspective on vulnerabilities complements Zhang's approach. This concept and the approach to manage it still require additional research and more clarifications.

5. Project Agility

The notion of agility in project management evolved from the Agile Manifesto for software development issued in 2001, which focused on lightweight methods to develop software applications [40]. The Agile principles include processes that emphasize being closer to the client, the iterative approach to better deal with disruptive events, daily meetings between team members to keep everyone updated on the status of the project, etc. [41]. Following the 2001 manifesto, the term Agile was adopted in many publications on project management [42], [43]. However, research on this concept is still mostly related to the software development sector [44], [45]. As concluded by Bianchi et al. (2020), an agile methodology is more adequate, and can prevent deviations, when requirements and needs are little known or unstable, especially in fast-changing contexts (mainly in the information technology field) [46].

Nevertheless, Conforto et al. [12], after a systematic literature review on the concept of agility in project management, pointed the fact that the project management literature has conflicting, incomplete, and ambiguous definitions of agility [12]. Therefore, Conforto et al.'s goal was to clearly define the concept of agility in project management. To achieve this objective, they surveyed 171 projects and, as a result, defined this concept in project management as "*the project team's ability to quickly change the project plan as a response to customer or stakeholders needs, market or technology demands in order to achieve better project and product performance in an innovative and dynamic project environment*" [12, p. 667].

Several points emerge from this definition. First, agility is defined as an ability (a quality or a skill). Second, the project team is the main entity, and the project plan is the primary element that needs to be modified or adapted. Finally, agility requires a transformation in response to the customers or stakeholders' needs or market and technology demands, which is not necessarily events that will deviate the project from its main objectives (disruptive events).

Werder and Maedche [45] argued that agility relies on two concepts: flexibility and leanness. Flexibility is defined as the capacity to initiate and to respond quickly to change (not necessarily a disruptive event). Leanness, on the other hand, aims to provide additional value based on the outcome of responding to a change [45]. Like Conforto et al. [12], these authors emphasize the importance of customers, users and stakeholders, which are, in many cases, the sources of changes. Therefore, agility is also about taking advantage of a change, embracing it, and learning from it to increase customer satisfaction. In fact, as mentioned by Morgan and Conboy, customers are always involved in the development process using agile methodologies. While the client is an important aspect of the agile process, it is possible to expand this technique to include different stakeholders [47].

As noticed by the definitions of the agility's concept, agility is less about proactivity (actions before the occurrence of a disruptive event) and more about reactivity (actions during or after the occurrence of a disruptive event) [48], [49]. It focuses on rapid response to change, mainly customers and stakeholders needs and demands. In relation to risk management, agile approaches manage possible future disruptive events that might be caused by the customers and stakeholders needs and demands in an implicit way (embedded in the way of perceiving and dealing with disruptive events). As mentioned by Nelson et al. [50] important steps of risk management are neglected in agile approaches such as defining guidelines and procedures, mitigation plans, risk repositories for tracking risks, etc. This shows the lack of proactive actions within the agile approaches [50].

Also, based on a study conducted by Tam et al. [51], these authors concluded to the fact that project success in agile projects strongly depends on the customer's collaboration and involvement. In addition, building the team capabilities through proper training and the development of teams composed of highly motivated individuals can also lead to successful projects from a time, cost and customer satisfaction perspective [51]. However, despite the importance of this study, emphasizing the type of change and its level of disruption needs to be analysed. Thus, additional items are needed to measure the ability of a project team to respond to change.

Therefore, from a project management perspective, focusing only on agility can, to a certain extent, make a project vulnerable [45], [52], because it does exist other events, outside the scope of customers and stakeholders' needs and market and technology demands that may disrupt a project. Therefore, it would be interesting to explore new avenues that focus on dealing with disruptive events and building a project's capacity to manage events that may cause a deviation from its main objectives. These avenues describe this study's objective of making projects more resilient.

6. Resilience in project management

The concept of resilience has existed for decades and applied in many disciplines. Consequently, its definition varies depending on the entity involved (an organization, a project, etc.); even when the focus is on a specific entity, definitions of resilience can vary substantially [53].

Resilience is mainly related to the system's capacity to maintain its functions and controls and the relationships between its various entities [54], [55] when faced with disruptive events.

It refers to a capacity for change and reorganization helping the system to return to its balance only gradually and, under certain conditions, will completely overhaul its structure and functions [56]. Resilience includes actions to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance. In fact, as highlighted by Carlson et al. [53], the system is initially in equilibrium. Therefore, anticipation, resistance and absorption actions are executed before the occurrence of an event that may disrupt this equilibrium. Alternatively, after the occurrence of a disruptive event, actions to respond, adapt and recover are undertaken. As a result, the resilience of the system "*determines both the amount by which the activity/well-being declines and the amount of time required to return to the pre-event equilibrium (or some other new equilibrium)*" [53, p. 18].

According to these aspects of resilience, recovery from disruptive events includes a set of activities or programs to effectively return to an acceptable state. This is debated in the literature, as some authors consider recovery to be a natural consequence of successful adaptation, which means that recovery and resilience are separate concepts. For instance, Stephenson [57] argues that organizational resilience has a direct impact on the pace and success of recovery from a crisis or disaster [57]. This perspective (recovery as a consequence of resilience) is also adopted in the work of Blay [5], who viewed recovery as a positive impact of resilience. She defined it as "*the improvement to the same or new set of objectives to ensure a successful completion of project endeavours*" [5, p. 218].

From a project management perspective, the concept of resilience is still novel and largely ignored [6]. It is new because, based on our research, there is no common understanding on the main elements that compose the concept of project resilience given the fact that any new field of research leads to a variety of definitions, methods, tools and processes [58]. To illustrate this fact, sometimes resilience is referred to as an ability, a capacity, or a capability to "restore capacity", to "evolve", to "maintain purpose and integrity", to "notice, interpret, contain", to "overcome", to “cope”, or to “reduce the impact”. All these terms can be defined in many ways based on the project’s context and characteristics. Also, the type of event that resilience is trying to deal with needs to be well defined. For example, some authors refer to resilience as the ability to deal with changes, others to emerging risks, to shocks, to unexpected events, or to uncertainties. Therefore, a rigorous conceptualization is needed. The shortage of resilience studies in project management is a powerful sign of the novelty of this concept. It is also to mention that Thomé et al. [7] found that scholars should pay more attention to the absence of coverage of the idea of resilience in the project management literature.

These statements among others encouraged academics to highlight resilience in project management. Naderpajouh et al. [59] proposed a conceptual framework that serves as a theoretical guide for additional research on the concept of resilience in project studies. From their perspective, resilience is defined as the analysis of how systems at various levels (individual, team, organization, project, industry, and society) function under a variety of circumstances, including disruptive events [59].

Varajão et al. [60] in their theoretical and practical study, emphasized the project team resilience. Thus, building a team composed of committed individuals that embrace conflicts and focus on results is key to face disruptive events. In addition, having an accountable leadership that formalize trust and solidarity through the right development of skills and the right acknowledgement of good behavior, improve work conditions and incite project teams to efficiently recover from disruptions [60].

Rahi [6] advanced the conceptualization on the concept of project resilience. After reviewing the literature on the resilience’s concept from many perspectives and in many fields, he proposed a conceptual definition and framework of project resilience. Two dimensions of project resilience were exposed: awareness and adaptive capacity. Awareness is related to the capacity of the project to explore its surroundings in order to close the gap between available and required resources. Alternatively, adaptive capacity is related to the capacity of the project to transform its structure in order to successfully recover from disruptive events [6], [13]. However, Rahi [6] concludes that what is provided is one of many viable approaches to describe project resilience, as with any new research concept. As a result, this is regarded as a clear constraint. Thus, additional research and academic investigations are needed to reinforce any tentative of conceptualization on the new concept of project resilience [6].

7. Comparative Analysis and Discussion

This section offers a critical analysis of the literature on risk management, vulnerability management, agility, and resilience to develop a conceptual framework among these concepts. It does so by reviewing the terminology and perspectives, and by highlighting the similarities and differences within the project management context. The analysis in this section will be conducted by thoroughly explaining Figure 2. This explanation will be supported by a case from the implementation of an IT application. An IT implementation project goes mainly through the following phases; launch, discovery (where the requirements and data are collected to better configure the application based on the client needs), configuration, tests, go live, support. The project team for this type of project is mainly composed of the project manager, the implementation consultants, and subject matter experts from both; the company side and the client side. The most important phase is the “go-live”, where the client will stop using its legacy system and start using the newly configured application. Therefore, not respecting the go-live date (which is fixed at the end of the discovery phase) may engender additional costs and many internal and external frustrations.

The first concept is risk management. Despite the fact that risk management practices is less implemented and used in industry [33], [36], these practices work well in low uncertain environments where the project is well defined and disruptive events can be easily (to a certain extent) identified (known events), assessed, and analyzed [31]. Thus, as shown in Figure 2, risk management is considered a proactive concept that addresses known risks, but it encounters difficulties in addressing unknown or unpredicted events [8], [32]. These risks might become disruptive events at a certain point in time during the project life-cycle. Risk management practices focus on dealing with the sources of known events without emphasizing the management of their consequences on the project’s objectives when these events occur [5]. This is because the consequences of these events, if they occur, are hardly predictable in advance due to the continuous dynamic changes on the project's conditions. Also, it is hard with actual risk management practices to identify *all* threats that may cause negative impact to the project. Therefore, more flexible practices are needed that take into consideration the characteristics of a disruptive event upon occurrence, and that offer actions to limit losses caused by this disruptive event as much as possible [62]. For example, in IT implementation projects, inaccurate collection of requirements at the discovery phase is considered a risk that can impact the configuration phase and lead to delays. This is a known risk that can be mitigated through rigorous follow-up with the client to get accurate information, or by informing the client that a sign-off is required at the end of the discovery phase where any changes during the next phases (configuration, testing, etc.) will engender additional costs. These actions can encourage the client to provide accurate information. However, what would be the consequences of configuring the application based on data that is not accurate? How to manage issues caused by this inaccuracy during the go-live phase where the frustration level is extremely high? That is why, complementing practices are needed to cope with this type of disruptive events.

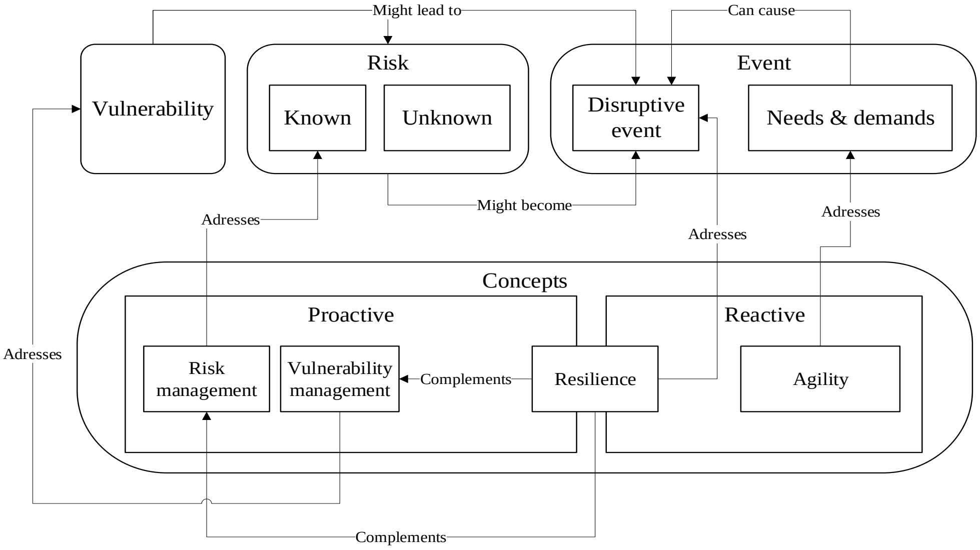

Fig. 2 – Conceptual framework between risk management, vulnerability management, resilience and agility from a project management perspective (inspired by Mochizuki et al. [61])

Vulnerability management is also a proactive concept that focuses on identifying, analyzing, and mitigating project weaknesses instead of risks as shown in Figure 2. In fact, dealing with project's weaknesses is important, it aims to reduce (to a certain extent) (1) the probability of having specific types of disruptive events, and (2) the susceptibility of the project to the disruptive events damaging effects [61]. For instance, having a senior implementation consultant may reduce the risk of poorly collecting requirements during the discovery phase, or the risk of having a poor configured application. However, for the system to withstand the effects of an event, not only should the event be known, but its context and the project's characteristics when the event occurred need to be understood and taken into consideration [38]. Thus, it is of equal importance to develop context-specific capacities to cope and recover from disruptive events along with the capacities to identify, analyze, and mitigate project vulnerabilities. For example, a vulnerability can be the presence of a junior implementation consultant instead of a senior one for an IT implementation project that requires a senior implementation consultant. This vulnerability may lead to poor collection of requirements and/or poor quality of configuration. Thus, making the project more susceptible to disruptive events with a lack of expertise and knowledge to effectively deal with these events. Therefore, vulnerability management aims to understand this type of vulnerability (among other types) and to prepare a mitigation plan to overcome them. However, vulnerability management does not eliminate the fact of having poor collection of requirements or poor configuration that may lead, for example, to severe issues in the go-live phase. In addition, even if a senior implementation consultant is part of the project team, with enough knowledge and expertise to deal with the consequences of poor configuration or poor collection of requirements, this senior team member can be absent when an issue caused by a poor configuration occurs. So, what to do in this case? How to cope with this issue? That is why additional practices are needed to cope with this type of event upon occurrence. Therefore, resilience thinking complements vulnerability management by offering coping strategies to improve the project capacity to cope with disruptive events on occurrence.

The third concept is agility. Agility is mainly used in IT projects and offers an iterations-driven approach to better capture and address clients' needs and demands during the project life-cycle [22]. Four points aim to distinguish between agility and resilience. First, agility focus on coping with events generated from changes on needs and demands to satisfy clients and stakeholders. These changes can cause disruptive events if not handled accurately. However, agility is not oriented toward coping with disruptive events on occurrence either caused by new needs or demands, or by other factors. For example, during an IT project life-cycle, having a technical difficulty with a software application used mainly by a software developer to produce an important deliverable, is a disruptive event that falls outside the scope of new needs from customers or stakeholders, or new technology or market demands. Therefore, other capacities are needed to cope with this type of disruptive events. Second, agility tends to ignore the organizational context in which the project is carried out [44]. Alternatively, from a resilience perspective, the project is on continuous interaction with its environment. These continuous interactions play a significant role in promoting project resilience [63]. Third, agility focuses more on reactive actions and less on proactive actions [48]. It focuses on changing specifically the project plan at the project level. This change is completed by the project team members [64]. Resilience, on the other hand, includes proactive and reactive capacities. It involves the ability to avoid or resist being influenced by an event as well as the ability to return to an acceptable level of performance in a reasonable amount of time after being affected by an event [49]. Resilience focuses on adapting the project as a system (not only the project plan). The adaptation could affect the project plan along with other elements like, for example, the project management information systems, the resources database, external partnerships, etc. Fourth, from a resilience perspective, the adaptation is related to the behavior of the system and its relationship with its environment. Therefore, it could be completed at the project's and/or the organization's level to contribute to the resilience of the project. Scaling agility framework does exist to promote agility at the organization level, but these frameworks are still facing many challenges to improve the relationship between the organization and the project, and to contribute in making the project more agile [65]. In fact, these frameworks aim to learn from the application of agility at the project level and adopt this knowledge at the organization level. In addition, these frameworks still require testing and validation to verify their applicability at the organization level [44]. As an example of agility, in an IT implementation project, agility offers strategies to keep the client and stakeholders involved through continuous meetings to quickly adapt to needs and demands. This adaptation can be achieved by updating the discovery document (a document issued at the end of the discovery phase), by advising the concerned implementation consultants, who in turn, adjust the configuration in consequence. However, what strategies are offered by the agility concept to deal with a technical dysfunction on the configured application when submitting your first official request through the application at the go-live phase? How to adapt to this kind of disruptive event? Therefore, additional practices and strategies are needed to cope with this type of event and to ensure as much as possible a successful delivery of the project's objectives.

The concept of resilience complements risk management and vulnerability management by (1) imbricating functional attributes relevant to practices aiming to deliver a system service when the system is in an acceptable state, and (2) by introducing a shift in the system to a desirable state when faced with disruptive events. In the second case, it is of equal importance to manage the system to benefit from the new desirable state once the shift is completed [66]. From a project management perspective, it is not only important to have the right tools to deal with risks (at the event level), with vulnerabilities (at the system level), or to deal with changes from the customers or stakeholders needs and requirements (at the stakeholders, clients and team members level). It is of equal importance to work on the project behaviour and to have the toolkit to think, act, and manage the consequences efficiently of disruptive events [67]. This behavioural work is important because it allows projects to adapt through a series of activities and actions when faced with disruptive events. Resilience helps reflect on the actions of the project and on the successful use of resources until adverse incidents are experienced. In other words, resilience is concerned with the development and realignment of systems, strategies, organizational structure, etc., to face all sorts of disruptive events. It offers insights into which elements contribute primarily to maintaining an appropriate level of performance for the project at a specific point in time (the time once the project is faced with a disruptive event). The definition of project resilience neither removes the need for risk management, vulnerability management or project agility nor disputes their importance. Instead, these perspectives contribute to project resilience, among other factors. Table 2 summarizes these objectives and limitations of the four concepts presented in this paper.

Table 2: Concepts to deal with risks/disruptions, their objectives and limitations

Type of method	**Proactive or reactive strategy**	**Deal with**	**Objective**	**Limitations**
Management of risks	Proactive	Threat and opportunities	Identify and analyze risks, prepare mitigation plans, and control risks during the project life-cycle.	Limited due to uncertainties, ambiguities and interdependencies between the project's elements [8], [16], [67]. Focus on risk sources rather than their consequences [62]. Not oriented toward empowering a project's capacity to deal with disruptive events [5], [68].
Management of projects' vulnerabilities	Proactive	Project's weaknesses	Reduce a project's vulnerabilities by managing weaknesses. These weaknesses may lead to disruptive events.	Focus on the disruptive events' sources rather their consequences [5], [68]. Reducing vulnerabilities may reduce the occurrence of risks, but do not necessarily manage them effectively if they occur [4], [62]. Not oriented toward empowering a project's capacity to deal with disruptive events [5], [69].
Project agility	Reactive	New customer or stakeholders' needs, or technology or market demands	Develop a project's capacity to change the project plan in response to customers' or stakeholders' needs, market or technology demands.	Does not necessarily focus on disruptive events; emphasizes the importance of customers and stakeholders. Focusing only on agility may make a project more vulnerable [38], [44]. Agility **as a concept** is still new; focuses mainly on the individual project, mainly in IT, and ignores the organizational context in which the project is carried out [37].
Project resilience	Proactive and reactive	Disruptive events	Foster a project's capacity to deal with disruptive events.	Resilience is still a new concept in project management that requires a clear conceptualization [67], [70]. Lack of empirical studies of this concept [7] Lack of indicators to assess resilience in project management [4], [5]. Studies of resilience in project management are mainly within the construction field (e.g., Blay [5]; Geambasu [4]).

8. Conclusion

This paper has provided a conceptual framework after reviewing the literature on risk and vulnerability management, project agility and resilience. It has applied the concepts specifically to implementation of IT projects.

As identified in the analysis, risk management is considered a proactive concept that addresses known risks, but it encounters difficulties in addressing unknown or unpredicted events. As stated, more flexible practices are needed that take into consideration the characteristics of a disruptive event upon occurrence, and that offer action to limit losses caused by this disruptive event as much as possible. Vulnerability management is also a proactive concept that focuses on identifying, analysing, and mitigating project weaknesses instead of risks. Resilience thinking complement vulnerability management by offering coping strategies to improve the project capacity to cope with disruptive events on occurrence. From a project management perspective, it is not only important to have the right tools to deal with risks, with vulnerabilities, or to deal with changes from the customers or stakeholders needs and requirements. It is equally important to work on the project behaviour and to have the toolkit to think, act, and manage the consequences efficiently of disruptive events. This behavioural work is important because it allows projects to adapt through a series of activities and actions when faced with disruptive events. Resilience is concerned with the development and realignment of systems, strategies, organizational structure, etc., to face all sorts of disruptive events. It provides insights into which elements primarily contribute to sustaining an appropriate project at a particular point in time (the time once the project is faced with a disruptive event). The concept of project resilience neither eliminates the need nor denies the relevance of risk management, vulnerability management or project agility. Instead, these perspectives contribute to project resilience, among other factors.

The above-mentioned factors and issues identified through this work offer pointers for further empirical research which may also be analysed with respect to other project environments including health, education, construction, etc.

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Abstract:
In this study, the success rate of projects in Turkey is measured, and the significant factors behind the successes and the failures of those projects are ranked. To the best of our knowledge, this is the first study widely measuring the success rate of projects in Turkey. The applied methodology is adapted from the Chaos Report by Standish Group. The data for 320 projects with a total budget of approximately $640 million (around 3.6 billion Turkish lira) is collected for the analysis. The results showed that 48% of projects are completed successfully while 45% are eventually completed but either over budget, not on time, or not fully completed. The success rate of the reviewed projects is higher than the rate reported in the Chaos Report. However, the success rate of projects drops to 44% when only technology-driven projects are considered. As the project size increases, the success rate diminishes, as demonstrated in the Chaos Report. The study on the significant factors influencing the success or failure of the projects revealed that the most critical factors are the “requirement definitions”, “requirement planning” and “top management support”.

Keywords:
project success rate; critical success factors; failure factors; technology-driven projects; Turkey.

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1. Introduction

Projects are defined as temporary endeavors to generate a unique product, service, or result [1]. Even though there have been major developments in project management over the years, the success rates of projects are still far from the desired levels [2],[3].

The number of studies focusing on project success has been increasing over the last few decades. However, most of these studies focus on either measuring project success or identifying the critical success factors of the projects with different characteristics. On the other hand, there is a limited number of studies that explicitly measure the success rates of projects even though measuring success is an essential part of the management process to develop tools, techniques, and management styles and to analyze the environmental factors that may support the success of projects with different characteristics.

In an attempt to increase the success rate of projects, it is essential to understand their success and failure rates [4]. This reality indicates a need for more studies to measure the success rates of projects with different characteristics and/or that are from different geographical locations. However, there has been no study widely analyzing the success rate of projects executed in Turkey from various industries and with different characteristics. In addition to measuring the success rates, the most critical project success factors need to be identified for projects executed in Turkey to understand the underlying factors behind their success/failure because the importance of those factors may be different for different countries. Therefore, this study aimed to measure the level of achievement of the completed projects either in the second half of 2019 or in the first half of 2020. The study also aimed to identify the significant factors behind the success and failure of the projects by analyzing the project data. An online survey method is used to obtain the data. The results are compared against similar studies to draw some conclusions.

Our contribution to the literature is threefold. First, it is the first study to measure project success rates in Turkey. By doing so, we contribute to the practitioners' understanding of success rates in different geographical regions since there is a limited number of such studies. Second, we identify how the critical success factors change in Turkey. Finally, the projects are classified into two broad categories: Technology-driven projects and non-IT-based projects. The difference in those categories' success rates helps in understanding the success rate differences in similar studies [2],[3].

The following section reviews the recent literature on project success. The applied review methodology is described in section three. Section four contains the results and the discussion of the analysis, and the article ends with conclusions and further research suggestions.

2. Background

Research on project success falls into two main categories: Studies dealing with the project success criteria and studies dealing with the critical success factors [4]. In the first category, there are many studies (e.g., [4]–[8]) discussing how the success of the projects should be measured and what criteria should be used. Even though the criteria to be used in project success measurement is quite controversial, cost, time, and quality (the iron triangle) are commonly used as the success criteria by researchers [9]. In one of the generally accepted definitions, project success is defined by the outcome criteria of the budget, schedule, performance, and client satisfaction [10]. In one of the recently published studies discussing how the success/failure rates of projects should be measured, Castro et al. [11] proposed generic project success criteria based on the quantitative surveys of 264 Brazilian project managers with different backgrounds. In another study focusing on the Information Systems (IS) projects, Pankratz and Basten [12] identified eight commonly accepted success criteria by interviewing eleven experienced project managers in Germany. Davis [6] assessed different views of project success by different groups of stakeholders and proposed a multiple stakeholder model to reconcile the different views.

In the second category of the studies, some researchers (e.g., [13]–[16]) discussed the critical success factors for projects with different characteristics. Project success factors may be defined as the input to the management system that led to the success of the project [5]. In a recent study, authors conducted a descriptive and explanatory study to analyze the impact of 38 critical success factors compiled from the current literature on project success factors [17]. Iriarte and Bayona [18] also reviewed the relevant articles that had been published until 2017 to synthesize the most referenced critical factors in information technology (IT) projects. In another study, Siddique and Hussein [19] investigated the similarities and dissimilarities between agile-based and waterfall-based projects based on how success is perceived and managed by interviewing 32 agile practitioners in Norway. Abylova and Salykova [20] also concluded that project success factors change according to the necessities and the priorities of the projects, and they added that there is still a need for more studies investigating the critical success factors because of the changing nature of the projects through time. After classifying the success factors and identifying the impacts of the factors on project performance, Tam et al. [21] investigated the five people-factors to identify the most contributing factors to the success of the agile software development projects by surveying 216 agile practitioners. Belassi and Tukel [22] concluded that not all critical success/failure factors are applicable to all projects because of their unique nature. They also concluded that environmental factors, such as political, economic, and social, impact the project's performance and need to be understood. As the political, economic, social, and cultural factors change from one geographic region to another, analyzing the impacts of those factors in different geographic regions may help both practitioners and academicians understand the underlying environmental factors behind the success/failure of the projects in those specific regions.

On the other hand, there is a limited number of studies explicitly measuring the success rates of projects even though the measurement is an essential part of the management process to develop tools, techniques, and management styles for improvement. Some of the studies measure the success of projects with different characteristics [3],[23], and others measure the success rate of projects limited to one specific area [2],[24],[25]. Standish Group has been measuring the success and failure rates of IT projects since 1985. It publishes the results in the Chaos Report each year [2]. In their study, Hughes et al. [24] designed a construction-business-specific survey to measure the success rates of the limited number of projects in the construction business. In another study, other authors reviewed 633 projects in South Africa to measure the success/failure rates of those projects, and they compared the results against the results of the Chaos Report [26]. Palcic and Buchmeister [27] conducted an online survey among Slovenian companies in 2010 and 2011 to determine the success levels of projects regarding different factors, such as company size, project type and company-project orientation. In another study measuring success/failure rates, Okike and Mphale [28] assessed the success rates of telecommunication projects by interviewing twenty managers from six different companies. They followed the definition of project success in the Chaos Report for assessing projects. In a study from Turkey on project success, authors measured the success rates of 70 IS/IT projects to examine how the investment assessment method, project size, and employed software development methodology affect project success. However, in the study, the number of the studies was limited to only 70, and the authors never revealed the success rates of the projects in different dimensions (i.e., time, cost and scope) and in various industries [29].

In the project management success literature, there is a distinction between project management success and project success. Project management success focuses more on cost, time, and quality. On the other hand, project success is more related to the success or failure of the project's outcome [4]. A Guide to the Project Management Body of Knowledge (PMBOK), published by the Project Management Institute in project management, considers success as achieving goals successfully within the previously drawn frame. "If a project has reached its original targets set by its client, activities are carried out as it should be, and a determined problem is resolved within the limits of time, cost and quality determined before; this project can be defined as successful [1]." The same definition of project management success is adopted in the study. This is also the definition used by the Standish Group in the Chaos Report. Following this perspective, the Chaos Report classifies projects into three groups: Successful, failed, and challenged.

- Successful project: The project is completed on time and on budget with all the requirements as initially defined.
- Challenged project: The project is completed but over-budget, over the estimate, or without some initially defined functionalities.
- Failed project: The project is canceled during the development, or the outcome of the project has never been used.

3. Methodology

In order to measure the success rate of the projects in Turkey and identify the most relevant critical success factors in reviewed projects, six-step survey development, data collection, and an analysis approach are applied in the study. Figure 1 defines the steps followed in the study. In the first step, the survey form is adopted. As defined in the background section, in this study, the definition of project management success from PMBOK is adopted, and the classification scheme is adopted from the Chaos Report. In the developed survey form, there are four sections and ten questions. The English translation of the survey form is presented in Appendix A. In the first section, the data regarding the company and the industry in which the projects are executed is collected. The collected data is later used to conduct industry-based analysis after classifying the projects. In the second section of the form, the data regarding the project size and the role of the respondent in the project are collected. The third section of the survey form includes the questions measuring the project success rates: the time, the budget, and the scope to classify the projects as successful, challenged and failed. Finally, in the last section of the survey form, respondents are asked to identify up to three most critical success/failure factors from a list of project success/failure factors for the project. The Chaos Report's critical success/failure factors are used in the list of project success/failure factors with some new success/failure factors identified in the current literature on project success/failure factors.

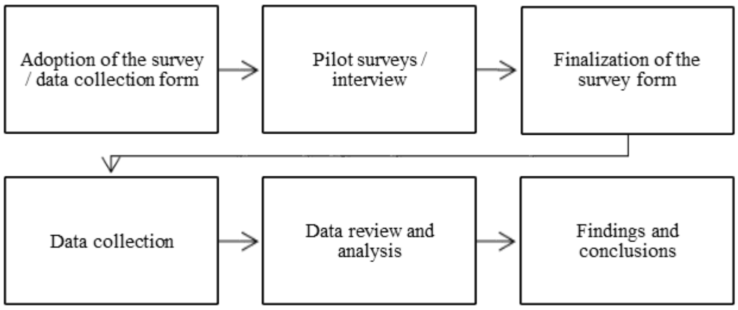

Fig. 1. The methodology applied in the study

After adopting the survey form into the study, in the second step, a limited number of face-to-face pilot interviews are conducted to ensure that the survey questions are straightforward and understood by the respondents. Then, the online survey form is finalized with the feedback gathered in pilot interviews in the third step. After finalizing the survey form, it was distributed to the potential participants, and they were asked to voluntarily fill out the survey form for each project completed in the last 12 months in which they either managed or had a significant role. The study participants are primarily members of two project management (PM) associations in Turkey: Istanbul Project Management Association and Project Management Institute — Turkey Chapter. The survey form has been sent to the members of those organizations. The survey form has also been sent to other project managers through personal and LinkedIn connections.

The data for 341 projects from various industries and over 200 organizations was collected through an online survey. Twenty-one responses are removed from the database for two reasons: There are redundant entries for the same projects, and some of the initiatives do not entirely fit the definition of the project. We eventually had data for 320 projects to conduct the analysis. In the next phase of the study, the data is classified into different groups and analyzed. Finally, the results are gathered and reviewed to generate valuable results and managerial insights. The results of the analysis are presented in the next section.

4. Results

In this section of the study, the results of the analysis are presented. First, the general statistics regarding the projects and the respondents are provided. Then, the measurement of the success/failure rates in terms of time, budget, and scope is presented. Finally, the most critical success and failure factors in the analyzed projects are presented and discussed.

4.1 General statistics for the reviewed projects

First, the general statistics regarding the reviewed projects, the companies, and the industries in which the projects are executed are presented in Table 1. As seen in the table, the data is collected from different industries, and there is a good mixture of industries to conduct an industry-based analysis of the projects. Along with the industry-based classification of the projects, other specifications of the projects and the respondents are also presented in Table 1. The dataset represents a total project budget of $641 million. The results presented in the table show that there is a good representation of the projects executed in Turkey regarding the various sizes of the projects and the companies. The table also shows that data is collected from the responsible people who have direct access to the project performance data, such as project managers or team members.

Table 1. Various specifications of the projects and respondents

Specifications	Variables	Count	Percent (%)
Industries	Banking & finance	36	11.2
	Information technologies	61	19.1
	Services	49	15.3
	Public services	38	11.9
	Telecommunications	13	4.1
	Manufacturing	58	18.1
	Misc. (engineering, health, retailing, etc.)	65	20.3
	Total	**320**	**100**
Company size	Large company (with 250+ employees or annual revenue of 125 M TL)	191	59.7
	Medium company (bw 50–250 employees or bw 25M–125M TL annual revenue)	53	16.6
	Small company (less than 50 employees and 25M TL annual revenue)	76	23.7
	Total	**320**	**100**
Project size	Very Small (Below $50K)	41	12.8
	Small (bw $50K–$250K)	56	17.5
	Medium (bw $250K–$1M)	78	24.4
	Large (bw $1M–$5M)	67	20.9
	Grand (Over $5M)	78	24.4
	Total	**320**	**100**
The role of the respondent	Project manager	171	53.4
	Project sponsor	19	5.9
	Project team members (e.g., specialist, developer, etc.)	100	31.4
	Other managers (e.g., head of project management office, functional manager, etc.)	12	3.7
	Other members (e.g., business unit, product owner, etc.)	18	5.6
	Total	**320**	**100**

4.2 *Measurement of project success*

Figure 2 presents the success rate of the reviewed projects. The results show that 154 (48.13%) of the reviewed projects are completed on time, on budget, and with the predefined scope (categorized as successful). On the other hand, only 22 (6.88%) projects failed, which means that the project is canceled before completion, or its output has never been used by the customer (categorized as failed). Those projects are also called “complete failure.” One-hundred-forty-four of the reviewed projects are completed but over-budget, over the estimate, or without some initially defined functionalities (categorized as challenged).

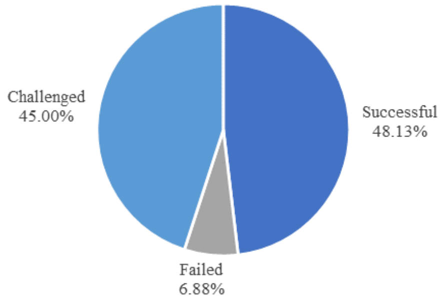

Fig. 2. Classification of the reviewed projects by their success

When the project success rate of the reviewed projects is compared with similar studies [2], [3], it can be concluded that the success rate is similar to the results of the PMI studies. However, the success rate is substantially higher than the success rate provided by the Chaos Reports. The difference may be explained by the type of projects. The Chaos Report measures the success rate of the IT-based projects only. However, in the present study, IT-based and non-IT-based projects are reviewed together.

Project success rates by industries:

How the success rates of the projects vary in different industries is also explored in the study (Figure 3). The results show that the success rate of the projects by industry varies. For example, manufacturing projects had the highest success rate at 64%, and telecommunications industry projects followed with a success rate of 54%. On the other hand, miscellaneous projects, including engineering, health, retail, and other sector projects, had the lowest success rate at 40%, which is slightly lower than banking & finance and IT projects success rates. The results are partially different from the analysis provided by Varajao et al. [30], in 2014. They concluded that software development and construction projects have similar success levels although the construction projects results are more positive in scope and time compliance.

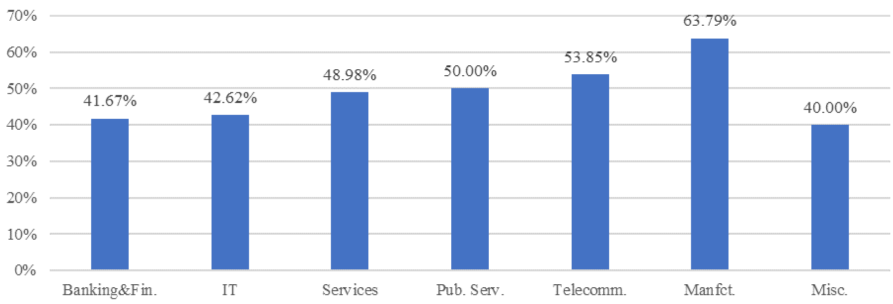

Fig. 3. The success rate of projects by industry

When the projects are classified into two broad categories, technology-driven (including IT, banking & finance, and telecommunications) and non-IT-based projects, the success rates of the projects in each category are calculated, as shown in Table 2. The table shows the difference between technology-driven and non-IT projects. That is, the project success rate is higher for non-IT projects. This may explain the significant success rate difference between the Chaos Reports (e.g., [2]) and the PMI studies (e.g., [3],[23]).

Table 2. Success rates of technology-driven vs. non-IT projects

	# of projects	Success rate (%)
Technology-driven projects	110	43.64%
Non-IT projects	210	50.48%

Project success rates by project size and company size:

The project success rate by project size and the company size with the industry breakdown (Tables 3 and 4) provide different views of project success. The success rate of the projects decreases steadily as the size of the project increases. The results support the idea that the size of the project is a critical factor in the success of a project. The project success rate decreasing as the project size increases shows that the larger the project, the lower the probability of completing the project on time, on budget, and with the predefined scope, as also concluded by Livesey [31] and Bezdrob et al. [32]. That may be explained by the increased need for team management and project management skills as the project size increases [31]. The decreasing success rate as the project size increases indicates the importance of keeping the size of the projects small whenever possible. On the other hand, an industry-specific analysis of project success rates does not identify any increasing or decreasing patterns in individual industries. This is probably because of the limited number of observations specific to each industry.

Table 3. Project success rate by project size with industry breakdown

Project size	Industry	Successful	Challenged	Failed	Total
	Banking & finance	2.6%	3.8%	1.3%	7.7%
	IT	3.8%	3.8%	3.8%	11.5%
	Services	1.3%	5.1%	0.0%	6.4%
Grand	Pub.Serv.	7.7%	3.8%	1.3%	12.8%
	Telecomm.	2.6%	1.3%	0.0%	3.8%
	Manufacturing	10.3%	3.8%	0.0%	14.1%
	Misc.	14.1%	25.6%	3.8%	43.6%
	Total	**42.3%**	**47.4%**	**10.3%**	**100.0%**
	Banking & finance	7.5%	4.5%	0.0%	11.9%
	IT	10.4%	13.4%	1.5%	25.4%
	Services	1.5%	9.0%	0.0%	10.4%
Large	Pub.Serv.	1.5%	10.4%	0.0%	11.9%
	Telecomm.	4.5%	4.5%	0.0%	9.0%
	Manufacturing	10.4%	3.0%	1.5%	14.9%
	Misc.	9.0%	7.5%	0.0%	16.4%
	Total	**44.8%**	**52,2%**	**3.0%**	**100.0%**
	Banking & finance	3.8%	10.1%	1.3%	15.2%
	IT	12.7%	10.1%	1.3%	24.1%
	Services	12.7%	6.3%	0.0%	19.0%
Medium	Pub.Serv.	3.8%	5.1%	0.0%	8.9%
	Telecomm.	1.3%	2.5%	0.0%	3.8%
	Manufacturing	10.1%	8.9%	0.0%	19.0%
	Misc.	2.5%	7.6%	0.0%	10.1%
	Total	**46.8%**	**50.6%**	**2.5%**	**100.0%**

Project size	Industry	Successful	Challenged	Failed	Total
Small	Banking & finance	5.4%	5.4%	0.0%	10.7%
	IT	8.9%	7.1%	7.1%	23.2%
	Services	8.9%	7.1%	1.8%	17.9%
	Pub.Serv.	8.9%	5.4%	1.8%	16.1%
	Telecomm.	1.8%	0.0%	0.0%	1.8%
	Manufacturing	12.5%	5.4%	0.0%	17.9%
	Misc.	7.1%	5.4%	0.0%	12.5%
	Total	**53.6%**	**35.7%**	**10.7%**	**100.0%**
Very Small	Banking & finance	5.0%	5.0%	0.0%	10.0%
	IT	2.5%	5.0%	0.0%	7.5%
	Services	17.5%	10.0%	2.5%	30.0%
	Pub.Serv.	10.0%	0,0%	0,0%	10.0%
	Telecomm.	0.0%	0.0%	0.0%	0.0%
	Manufacturing	17.5%	7.5%	5.0%	30.0%
	Misc.	7.5%	2.5%	2.5%	12.5%
	Total	**60.0%**	**30.0%**	**10.0%**	**100.0%**

Table 4. Project success rate by company size with industry breakdown

Company size	Industry	Successful	Challenged	Failed	Total
Large	Banking & finance	7.9%	9.4%	1.0%	18.3%
	IT	4.7%	6.3%	1.6%	12.6%
	Services	5.2%	5.2%	0.5%	11.0%
	Pub. Serv.	7.9%	7.9%	1.0%	16.8%
	Telecomm.	3.1%	3.1%	0.0%	6.3%
	Manufacturing	11.0%	4.2%	0.5%	15.7%
	Misc.	6.8%	12.0%	0.5%	19.4%
	Total	**46.6%**	**48.2%**	**5.2%**	**100.0%**
Medium	Banking & finance	0.0%	0.0%	0.0%	0.0%
	IT	15.1%	5.7%	3.8%	24.5%
	Services	7.5%	3.8%	0.0%	11.3%
	Pub. Serv.	7.5%	1.9%	0.0%	9.4%
	Telecomm.	0.0%	0.0%	0.0%	0.0%
	Manufacturing	15.1%	11.3%	1.9%	28.3%
	Misc.	11.3%	13.2%	1.9%	26.4%
	Total	**56.6%**	**35.8%**	**7.5%**	**100.0%**
Small	Banking & finance	0.0%	0.0%	1.3%	1.3%
	IT	11.8%	14.5%	5.3%	31.6%
	Services	13.2%	14.5%	1.3%	28.9%
	Pub. Serv.	0.0%	1.3%	0.0%	1.3%
	Telecomm.	1.3%	0.0%	0.0%	1.3%
	Manufacturing	10.5%	5.3%	1.3%	17.1%
	Misc.	9.2%	6.6%	2.6%	18.4%
	Total	**46.1%**	**42.1%**	**11.8%**	**100.0%**

An analysis of the project success rates of various company sizes may draw some conclusions. The projects carried out in medium-sized companies (annual revenue between 25 million and 125 million Turkish lira) had the highest success rate at 56.6%. The project success rates of small enterprises and large enterprises are 46.1% and 46.6%, respectively. However, no upward or downward trend as the company size increases is observed. On the other hand, as the company size increases, the failure rate of the projects decreases from 10.5% to 7.5% and then 5.2%. The change may be explained by the variety of additional resources that the large companies may provide to the projects with time or cost overruns. This indicates that the large companies are more successful in preventing overrun projects from becoming complete failures. The companies in the banking & finance, telecommunications, and public services industries are primarily large. In the IT and services industries, success rates follow the general pattern (i.e., the highest at medium-sized). In the manufacturing industry, the success rate is highest for large companies, and, in the miscellaneous category, the success rate increases as the company size decreases.

Next, the performance of the reviewed projects in individual performance metrics (time, budget, and scope) is presented. Figure 4 shows the ratio of the projects completed within a reasonable estimated time. One hundred ninety-two out of 320 projects are completed on time without delay from the estimated project completion time. The remainder of the projects (128 out of 320) show time overruns. The reviewed projects are the least successful in terms of time. Figure 5 presents the ratio of the various levels of time overruns of the delayed 128 projects. Thirty-nine projects have a time overrun of 50% or more, and the average time overrun ratio is calculated as 14.0% for the reviewed 320 projects. The time overrun ratio is calculated as 17.0% when only the IT-based projects are considered. The ratio reported in the Chaos report was 16.6% [2].

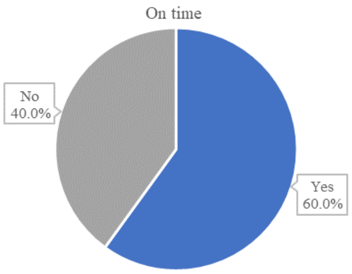

Fig. 4. The ratio of projects completed within a reasonable estimated time

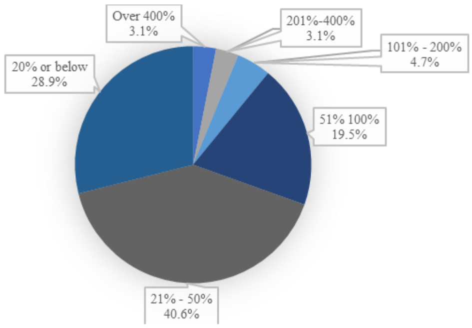

Fig. 5. Time overrun ratios (out of 128 projects)

Figure 6 depicts the ratio of the projects that stayed within the budget when they were completed. Two hundred thirty-one (72%) out of 320 projects stayed within the budget when they were completed. The remainder of the projects (89 out of 320) showed a cost overrun or were never completed. The success rate of the projects is higher in terms of finishing the projects within the budget than finishing them on time. Figure 7 presents the ratio of the various levels of the cost overruns. Nineteen projects have a cost overrun of 50% or more. The results also show that the average cost overrun ratio is 11.8%. The cost of that overrun is $227 million only for the reviewed projects. The ratio reported in the 2019 Chaos Report was 18.2% [2]. The difference between the ratio calculated in this study and the Chaos Report can again be explained as having non-IT-based projects in the database because the cost overrun ratio is higher (18,7%) only when IT-based projects are considered.

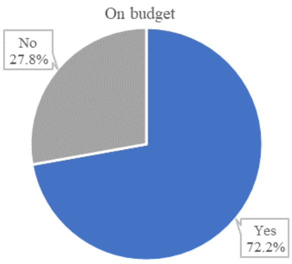

Fig. 6. The ratio of the projects stayed within the budget

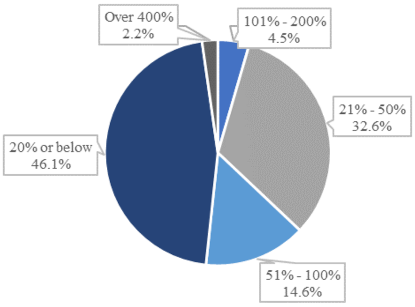

Fig. 7. Cost overrun ratios (out of 89 projects)

Figure 8 classifies the reviewed projects into three groups: The projects completed with the predefined scope (onscope), the projects missing at least one critical initially defined functionality (completion with missing functionality), and the projects canceled during the development or that have never been used (canceled or never used). Out of three different dimensions of the project performance, the reviewed projects are most successful in completing the projects with the predefined scope (around 84% of the projects). On the other hand, around 9% of the reviewed projects had not delivered at least one critical predefined functionality when the project was completed. Finally, around 7% of the projects had never been completed or had never been used by the customers even though the project had been completed and delivered.

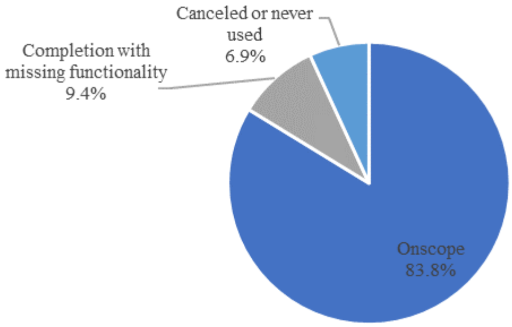

Fig. 8. Classification of projects by completion of the scope at the end of the project

4.3 Critical success factors

In the last subsection of the analysis, the study results on the most critical success and failure factors are presented. The results are based on the data collected in section four of the survey form. A list of critical success or failure factors gathered from relevant studies (mostly Chaos Reports) identified in the literature review is provided in the survey form. The list of factors is also presented in Figures 9 and 10. The respondents were asked to select up to three success factors most relevant to the reviewed project if they believed that the project was successful. Figure 9 depicts the critical success factors ranked by their ratio of appearance in the responses. The ratios provided next to the factors show the ratio of their selection as a critical success factor. According to the responses, the clear definition of the requirements is the most important critical success factor at 41.3%. Then, it is followed by proper planning (at 38.8%) and executive management support (at 31.9%). The results show similarities with similar studies in the literature; however, there are some minor differences. Even though the importance of the requirements definition is underlined in all the studies, the respondents put more importance on requirements definition in the reviewed projects. In addition, no one can ignore the importance of proper planning in project management; however, it does not appear in the list of the three most critical factors in similar studies. The respondents also believe that executive sponsorship is critical for the success of the projects, but they do not pay that much attention to the project sponsor, who is assumed to be a part of top management.

The results of the critical success factors for each industry are also presented in Appendix B.1. The industry-specific analysis also gave some conclusions. Even though "clear definition of the requirements" is the most important critical success factor when the industries are combined, the most important critical success factor is "executive management support" in the banking & finance, public services, and telecommunications industries. Project team-related factors (i.e., "hard-working, focused staff" and "competent staff") are ranked as the most critical factors in the services industry. "Proper planning" is ranked as very important in telecommunications, manufacturing, and miscellaneous industries; however, it is not ranked as one of the three most important factors in other industries.

The respondents were also asked to select up to three failure factors that are most relevant to the reviewed project if they believed that the project was not successful. Figure 10 shows the most critical factors behind the projects' failure, as identified by the participants in the study. The critical failure factors are also ranked by their ratio of appearance in the responses. The results show that the requirements definition is the most critical factor in the failure of the projects as it is in the critical success factors. One interesting result is that three out of the five most important factors behind the failures of the projects are "unrealistic expectations," "lack of resources," and "lack of executive support." These factors are the factors that the project team or project management does not directly affect. Therefore, it can be concluded that the participants in the study believe that the factors they cannot directly control are more critical in the failure of the projects. On the other hand, the participants also confirmed the importance of managerial factors, such as "top management support," "adequate planning," "realistic expectations," "change management," etc., on the success of the projects.

Fig. 9. Critical success factors (ratio of appearance for each factor)

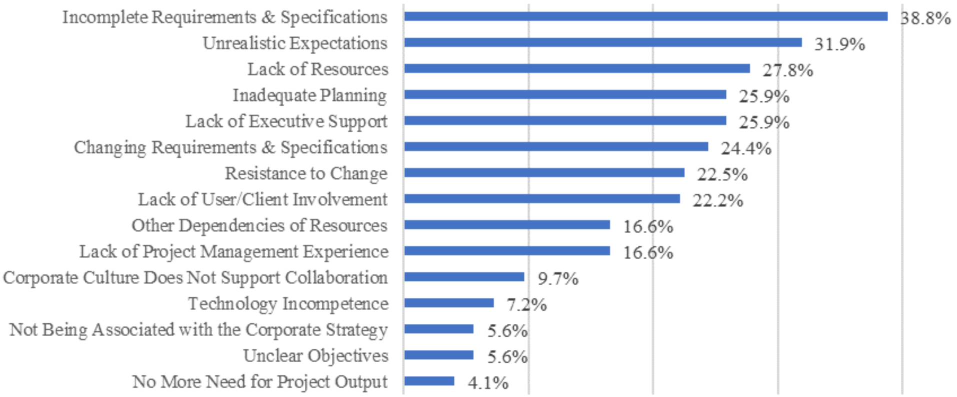

Fig. 10. Critical failure factors (ratio of appearance for each factor)

The results of the critical failure factors for each industry are also presented in Appendix B.2. Some conclusions may be drawn from the industry-based analysis. "Incomplete requirements & specifications" is generally ranked as the most critical factor or at least one of the three most important factors. Only in manufacturing industry projects is it not ranked as one of the most critical factors. In the manufacturing industry, "unrealistic expectations" is ranked as the most critical factor in the failure of the projects. "Lack of resources" is believed to be a critical factor in manufacturing and telecommunications industries, but not in banking & finance and public services industries. According to the results, "resistance to change" is a significant issue in the banking & finance, IT, services, and public services industries. However, it is not considered a critical factor in the telecommunications and manufacturing industries.

5. Conclusions and further research suggestions

This study presents the success rate of projects completed in Turkey in the second half of 2019 or the first half of 2020. The critical success and failure factors are also ranked to understand which factors are the most important in the success or failure of the reviewed projects. The study shows that around 48% of the reviewed projects are completed on time, on budget, and with the predefined scope. The study revealed a higher success rate than the Chaos Report and a somewhat lower success rate than the PMI study. When the projects were grouped into two groups, technology-driven projects and non-IT-based projects, the analysis indicated a significant success rate difference between these two groups. The non-IT-based projects had around 51% success rate; however, the IT-based projects had only a 44% success rate. The study also helps explain the significant success rate differences between the PMI study and the Chaos Report.

The success rates of different industries are also explored in the study. The results show that the success rate of the projects by industry varies, and the success rates are lower for the industries that generally have technically more complex projects, such as IT and banking & finance. On the other hand, the manufacturing or services industries have higher success rates than average. The analysis confirmed the general idea that the project success rate decreases as the project size increases. The result implies that the project size should be kept as small as possible to reduce the complexity and increase the probability of completing projects successfully.

The projects are least successful in completing the project within a reasonable estimated time (60%). They are most successful in completing the projects with the predefined scope (84%), while 72% of the projects stayed within the budget when they were completed. The average time overrun ratio for the reviewed project is 14.0%, and the average cost overrun ratio is 11.8%, which is equivalent to $227 million. This result implies that the project management teams should focus more on project scheduling and project time management.

The most critical factors identified in the study concern the requirements definition and management, which are also commonly identified critical success factors in the literature. Furthermore, the analysis showed that three out of the five most important factors behind the failures of the projects are "unrealistic expectations," "lack of resources," and "lack of executive support" on which the project team or the project management does not have a direct impact. Therefore, it can be concluded that the participants believe that the factors that they cannot directly control are significant in the failure of the projects. Moreover, the participants also confirmed the importance of the managerial factors, such as "top management support," "adequate planning," "realistic expectations," and "change management" on the success of the projects.

One major limitation of the study is that it is applied to the projects completed only in Turkey for a certain period. This study may be applied to different geographical regions in future studies. For example, the success rate of projects executed in Europe from different countries may be analyzed. Then, the success rates of various countries may be compared. In addition, in the following years, the study may be repeated to depict how the success rates change throughout the years. Another limitation of the study is that there was a limited number of observations for individual industries. The number of observations was sufficient to compare various industries' success/failure rates; however, more observations were required to analyze how the success rates change within an industry based on project size and company size. Therefore, the research may be repeated with more observations to study how the success rates change within the study as the company size and project size increase. In the analysis, there was limited information regarding the company and the project team. By collecting more information about the company and project team, such as the company culture, leadership style, and project team organizational structure, the relationship between these factors and project success may also be investigated. There is also a need for more researches investigating Turkish cultural idiosyncrasies and their impact on the project success and critical success factors.

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Appendix A. Survey form

Section I. Company Information

1) Which industry is your company? *Please select one.

☐ Banking and Finance
☐ Public Services
☐ Information Technologies
☐ Manufacturing
☐ Telecommunications
☐ Other Services
☐ Retailing
☐ Other: Please specify ________________

2) Please specify the size of your company?

- Small company (Less than 50 employees and annual net revenue of less than 25 million TL)
- Medium size company: (Less than 250 employees and annual net revenue of 125 million TL)
- Large company (More than 250 employees or annual net revenue of more than 125 million TL)

Section II: Project General Information

3) Please specify the name of the project: Please make sure the project is not still under development

____

4) Project budget? * Please specify one.

☐ Grand (Budget over $5 M)
☐ Large (Budget between $1 M and $5 M)
☐ Medium (Budget between $250 K and $1 M)
☐ Small (Budget between $50 K and $250 K)
☐ Very Small (Budget below $50 K)

5) What is your role in the project? *Please specify one.

☐ Project Manager
☐ Project Team Member
☐ Project Sponsor or Business Unit Manager requested the project
☐ Other: please specify _____________

Section III: Project Success Metrics

6) Is the project completed on time without any delay from the estimated project completion time?

☐ Yes → Go to 8
☐ No → Go to 7

7) Please specify the time overrun in the project?

☐ 20% or below
☐ 21% - 50%
☐ 51% - 100%
☐ 101% - 200%
☐ 201% - 400%
☐ Over 400%

8) Is the project within the budget when it is completed?

☐ Yes → Go to 10
☐ No → Go to 9

9) Please specify the cost overrun in the project?

☐ 20% or below
☐ 21% - 50%
☐ 51% - 100%
☐ 101% - 200%
☐ 201% - 400%
☐ Over 400%

10) Is the project delivered with all the specifications/functionalities previously defined in the project scope?

☐ Yes
☐ No (One or more functionalities defined in scope are not delivered when the project is completed.)
☐ The project has been canceled during the development or never been used.

Section IV: Project Success and Failure Factors

11) Which factors do you believe are the most critical factors in the success of the project if you consider the project successful? Please specify up to three factors from the list provided.

- The list of the factors is provided in section appendix B.

12) Which factors do you believe are the most critical factors in the failure of the project if you do not consider the project successful? Please specify up to three factors from the list provided.

- The list of the factors is provided in section appendix B.

Appendix B. Critical success/failure factors in various industries

B.1. Critical success factors in various industries

Critical Success Factor	Banking & Finance	IT	Services	Public Services	Telecomm.	Manufact.	Misc.	Total
Clear Statement of Requirements	30.6%	45.9%	30.6%	39.5%	38.5%	44.8%	49.2%	41.3%
Proper Planning	33.3%	31.1%	30.6%	39.5%	53.8%	43.1%	47.7%	38.8%
Executive Management Support	52.8%	24.6%	26.5%	44.7%	38.5%	32.8%	21.5%	31.9%
Hard-working, Focused Staff	36.1%	31.1%	34.7%	28.9%	23.1%	19.0%	27.7%	28.8%
User/Client Involvement	36.1%	37.7%	22.4%	18.4%	30.8%	32.8%	20.0%	28.1%
Competent Staff	13.9%	19.7%	34.7%	13.2%	23.1%	29.3%	35.4%	25.6%
Project Ownership	27.8%	24.6%	24.5%	36.8%	23.1%	20.7%	21.5%	25.0%
Project Management Expertise	5.6%	34.4%	22.4%	21.1%	7.7%	20.7%	27.7%	22.8%
Realistic Expectations	19.4%	9.8%	18.4%	5.3%	23.1%	10.3%	13.8%	13.1%
Strong Relationship Between Project and Organization Strategy	19.4%	6.6%	8.2%	10.5%	23.1%	10.3%	6.2%	10.0%
Existence of Clearly Defined Project Milestones	8.3%	6.6%	18.4%	2.6%	0.0%	10.3%	9.2%	9.1%
Collaborative Organizational Culture	5.6%	9.8%	6.1%	10.5%	7.7%	8.6%	9.2%	8.4%
Clear Vision & Objectives	8.3%	8.2%	12.2%	7.9%	0.0%	6.9%	4.6%	7.5%
Effective and Skilled Project Sponsor	2.8%	6.6%	2.0%	5.3%	7.7%	5.2%	0.0%	3.8%
Emotional Maturity	0.0%	1.6%	4.1%	2.6%	0.0%	1.7%	1.5%	1.9%

B.2. Critical failure factors in various industries

Critical Failure Factors	Banking & Finance	IT	Services	Public Services	Telecomm.	Manufact.	Misc.	Total
Incomplete Requirements & Specifications	58.3%	47.5%	34.7%	28.9%	38.5%	24.1%	41.5%	38.8%
Unrealistic Expectations	19.4%	36.1%	26.5%	26.3%	30.8%	37.9%	36.9%	31.9%
Lack of Resources	16.7%	29.5%	30.6%	15.8%	46.2%	34.5%	27.7%	27.8%
Inadequate Planning	36.1%	18.0%	32.7%	28.9%	38.5%	20.7%	23.1%	25.9%
Lack of Executive Support	41.7%	19.7%	28.6%	28.9%	38.5%	24.1%	18.5%	25.9%
Changing Requirements & Specifications	41.7%	19.7%	28.6%	28.9%	38.5%	24.1%	18.5%	25.9%
Resistance to Change	27.8%	34.4%	26.5%	26.3%	7.7%	17.2%	20.0%	24.4%
Lack of User/Client Involvement	11.1%	26.2%	20.4%	28.9%	7.7%	25.9%	23.1%	22.5%
Other Dependencies of Resources	27.8%	24.6%	24.5%	10.5%	15.4%	24.1%	21.5%	22.2%
Lack of Project Management Experience	16.7%	18.0%	8.2%	23.7%	7.7%	20.7%	15.4%	16.6%
Corporate Culture Does Not Support Collaboration	16.7%	18.0%	8.2%	23.7%	7.7%	20.7%	15.4%	16.6%
Technology Incompetence	5.6%	14.8%	8.2%	13.2%	23.1%	22.4%	26.2%	16.6%
Not Being Associated with the Corporate Strategy	11.1%	3.3%	14.3%	13.2%	15.4%	6.9%	10.8%	9.7%
Unclear Objectives	8.3%	6.6%	8.2%	2.6%	0.0%	5.2%	4.6%	5.6%
No More Need for Project Output	2.8%	6.6%	12.2%	2.6%	7.7%	1.7%	6.2%	5.6%

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Implementation of Building Information Modelling in infrastructure construction projects: a study of dimensions and strategies

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Abstract:
The emergence of Building Information Modelling (BIM) has revolutionized the infrastructure construction industry by introducing real-time and collaborative information management tools to be used throughout the lifecycle of projects. The importance of BIM in this industry has been emphasized in previous research. However, strategies for the implementation of this system is still less explored, which requires more elaboration and validation. The purpose of this paper is to investigate such strategies considering all necessary dimensions of the BIM system in infrastructure construction projects. The findings are based on theoretical discussion and semi-structured interviews in a case study project in New South Wales, Australia. The results revealed that BIM integrates various elements of infrastructure construction, which include but are not limited to risk, time, cost, energy, safety, and sustainability. It was found that implementation strategies should focus on improving the contribution of the BIM system to infrastructure construction in terms of improved (1) integrity and automation, (2) collaboration, and (3) optimization. Identification of seven technical and managerial implementations strategies is the core contribution of this research. These strategies provide practitioners with insight into technical and managerial measures to be taken for the successful implementation of the BIM system.

Keywords:
information systems; Building Information Modelling; BIM; BIM dimensions; construction project delivery; construction industry.

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1. Introduction

Infrastructure as the building block of industrial and urban development benefits from information systems to address complexities. Proper use of modern information technology tools enhances cross-organizational and cross-departmental communications and provides a robust basis for collaborative design and construction. Introducing modern information systems improves agility in decision making and project delivery by reducing lead time [1]. The demonstrated impact of information systems on automated cost analysis [2], safety management practices [3], and management of operation and maintenance during the facility lifecycle [4] have encouraged construction organizations to implement different forms of information systems. Computer-aided design (CAD) is one of the prerequisites of automation in construction projects and information systems significantly contribute to distributing graphical representations of a facility [5] with stakeholders in a three-dimensional setting [6]. Information systems contribute to more effective management of project documentation and keeping up-to-date records of key project documents such as drawings, contracts, charters, and plans [7]. In large infrastructure projects, instant distribution of performance information among different stakeholders enables them to liaise with clients more effectively to coordinate actions for implementing sustainability initiatives [8] and construction plans [9].

With numerous stakeholders and technologies involved in the execution and delivery of infrastructure projects, the need for employing information systems is becoming more evident since they capacitate clients and contractors to enhance their communication and information exchange capacities [10]. Information systems provide a suitable basis for collecting, processing, storing, and sharing data related to the construction and operation of a facility. They contribute to the more agile management of data generated during this process [11]. The visualization and analysis of the information obtained from different teams involved in the process of infrastructure construction enable main contractors to identify errors and shortcomings of project plans, engineering designs, and architectural drawings before initiating the construction activities [8]. The dissemination of computer-aided design in these activities benefits contractors in terms of higher integration of design features with construction steps so that the possible conflicts and errors in the delivery stage are controlled. Integrated information systems store important data from each discipline and interlink them to ensure that all technical requirements of a facility have been incorporate early in the design and configuration stage [12].

The emergence of the Building Information Modelling (BIM) system restructured the mechanisms of collecting, analysing, and transmitting information among construction stakeholders [2]. With the ever-increasing importance of agile and lean construction methods, information technology tools are being frequently discussed in light of building information modelling (BIM) as an integrated platform allowing the interdisciplinary link of subsystems and building engineering mechanisms. Today’s construction industry is in an important era to drive a shift in the infrastructure construction sector from traditional methods to more systematic and advanced technologies. The dynamic and competitive construction market has led contractors to execute several projects simultaneously and deliver them with the highest quality to maintain their position in the market. Previous research underlined the importance of BIM in construction projects and highlighted its capabilities in coordinated design, production, communication, and data analysis [5]. The focus of prior studies was mainly to study specific aspects of building information modelling. Among such studies, it is noteworthy to acknowledge novel studies conducted by Montiel-Santiago et al. [8] that analysed the energy efficiency of buildings using BIM systems or the study conducted by Hassan et al. [2] on the application of five-dimensional BIM in improving construction estimations.

Although former studies endeavoured to determine the role of BIM in the construction industry, further research would consider examining the contribution of the BIM system and the potential strategies for implementing this system in infrastructure construction projects. This gap justifies undertaking a dedicated study to further elaborate on prerequisites and initiatives for achieving more effective BIM systems in the infrastructure sector. The current study aims to consolidate perspectives of prior studies and adds the viewpoints of experts on (1) the contribution of each possible dimension of the BIM system to infrastructure construction project delivery, as well as (2) potential strategies to implement the BIM system in infrastructure construction projects. The role of BIM is highlighted to explain how this system helps managers anticipate potential issues throughout all stages of design and construction through a digital representation of building characteristics.

The content of this paper has been structured as follows. The literature review section explains the theoretical background and concepts of BIM. The dimensions of BIM, success factors for effective implementation of this system, as well as the information systems needed for implementation of BIM are explained based on the findings of prior studies. The methods section explains the methodological approach used for data collection and analysis. The findings of the study were explained thereafter in terms of (1) the contribution of the BIM dimensions to infrastructure construction and (2) strategies for the implementation of the BIM system. The findings were followed by the discussion and conclusion section to discuss and conclude the main findings.

2. Literature review

2.1 Dimensions of Building Information Modelling

As a result of the literature survey, it was revealed that 10 dimensions characterize the full functionality of a BIM system. Figure 1 provides an overview of the dimensions of the BIM system and the incorporation of the important aspects of construction projects. The dimensions 1D to 7D have been in place since the early 2000s by using proper software packages [6]. However, 8D to 10D still need more elaboration and development to be used by companies in the infrastructure construction sector. In the simplest form, BIM documents procedures and important technical specifications of a facility while a sophisticated BIM system is capable of integrating important aspects of construction project delivery such as safety, lean construction, and automation [1].

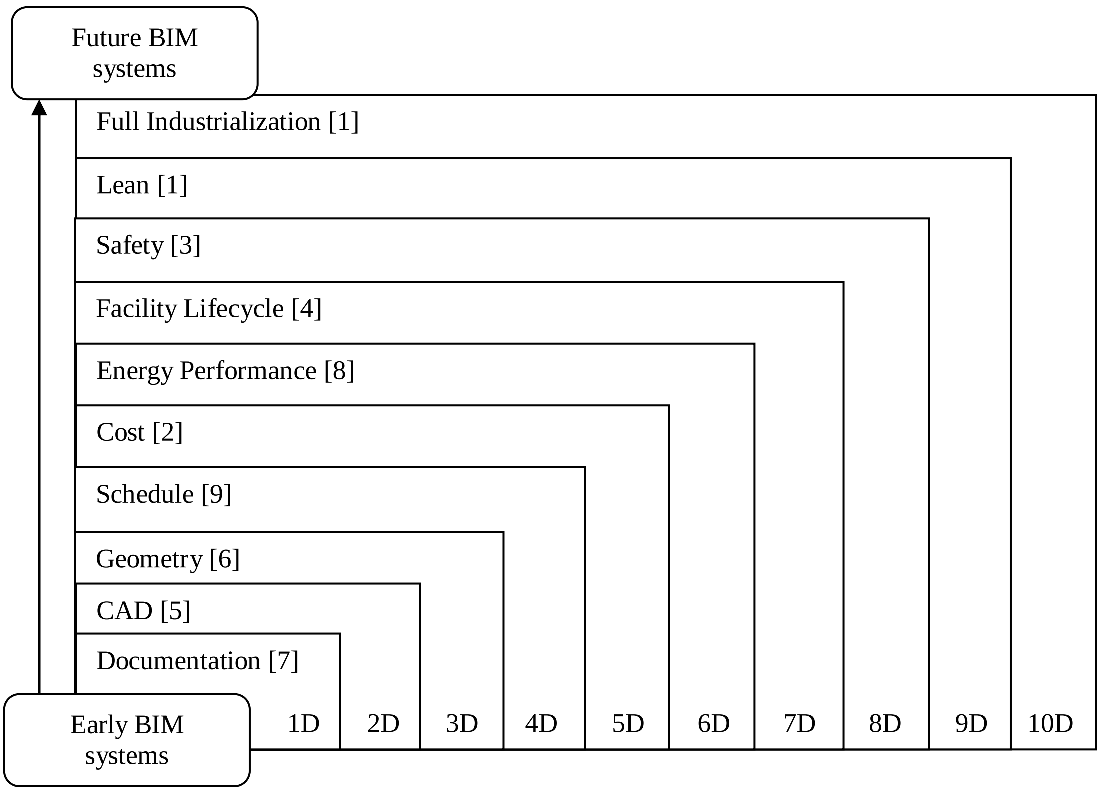

Figure 1: The dimensions of the BIM system

1D BIM: The preliminary foundation of BIM is the documentation of all requirements associated with the construction project lifecycle. The dispersed information from stakeholders and teamwork is integrated into the BIM platform to form a basis for managing changes to configuration and documents. Documentation clarifies the process of producing and sharing important information during the commissioning period of the infrastructure construction project. The structured set of project documents facilitates the information management process and enables project managers to exchange information among the project team members and keep them on track with consistent access to engineering specifications, architectural drawings, features of the equipment, and product requirements [7]. Proper document management is a prerequisite to processing changes and keeping records of different versions of documents. The access of internal and external stakeholders to documents is defined in the document management system, allowing real-time access to a comprehensive archive. The centralization of all important documents essential for planning, delivery, and management of a facility helps owners to gain deep insight into the dimension of information and its distribution among stakeholders. This aspect of BIM streamlines various stages of the infrastructure construction process.

2D BIM: Modelling a project in two dimensions is limited to a simple X-axis and Y-axis representation of project design and drawings. Planning is primarily conducted in two dimensions and relates constraints and objectives to the project specifications. 2D BIM, as the earliest form of construction models, allows fundamental planning activities to be performed faster and in a simpler format. However, in large and complex infrastructure projects, more elaboration is needed to ensure that cost-effective flawless plans and designs are generated and in place to support on-target construction project delivery. With the inclusion of more variables and constraints, detailed planning becomes more complicated and the need for visualizing the parameters arises [5].

3D BIM: Undertaking design and planning in a three-dimensional environment increases the clarity and rigour of the process. It entails integration and visualization of the graphical and non-graphical information ranging from space relationships and isometrics to estimated quantities [13]. Possible physical clashes in the construction of different components are simulated and designers can improve the quality of the outcomes. This is a kind of quality assurance for the design documents that removes errors and increases the compliance of projects with quality standards. Any updates such as further developments, changes, and demolition can be managed in a more organized way. The 3D BIM is an aid for stakeholders to coordinate their multidisciplinary activities and analyse structural features of the components. Accurate data on three aspects of the model is collected and stored in a database to be used in stages of the lifecycle. The 3D BIM adds space to the traditional 2D CAD (Computer-Aided Design) drawings and provide more profound insight into the graphical features of a facility. As a virtual representation of the visual details of a facility, 3D BIM helps architects to identify conflicts in the design documents. Pre-construction visualization is the best risk avoidance strategy to decrease major conflicts of design features during the stages of constructing a new facility [6].

4D BIM: Incorporation schedule into the 3D model of a facility enables detecting errors in timing and the sequence of activities. Project schedules are to be rigorously checked against any conflicts and interferences in the hard or soft logic of the activity dependencies that seem problematic. The progression of the scheduled activities is simulated using the BIM analytical tools so that the activity network can be optimized and improved. Sequential development of the installations, excavations, and other construction activities, as well as the lags such as curing time, is demonstrated throughout this process to ensure constructability and consistency of schedules. Adding another dimension to the graphical 3D model of the facility, a more accurate schedule is developed after construction phasing simulation and rectifying operational inefficiencies as well as logistical issues [9].

5D BIM: This dimension of BIM incorporates cost estimates into 4D BIM to enable integrated cost planning and project budgeting. The budget software, scheduling software, and BIM 3D model interoperate seamlessly so that estimators can analyse capital and operating costs during the construction stages. The sensitivity of the costs involved in the execution of each activity is analysed visually over time, which allows automated quantity surveying towards achieving a realistic budget. This tool can be used during the stages of infrastructure construction by keeping track of budget deviations from the baseline target. Elements of the 5D BIM should capable of extracting and visualizing accurate cost-related information that can be shared among estimators, owners, investors, and contractors [2].

6D BIM: The 6D BIM optimizes energy consumption and reduces the long-term costs associated with running the facility and improves performance. This dimension of BIM significantly contributes to sustainability objectives and creating a green infrastructure by conserving energy in the infrastructure construction sector. Accurate prediction of energy construction requirements and upfront costs of projects gives insight into the entire costs of managing a facility, which helps designers to adopt a long-term view of engineering specifications. A sensitivity analysis can be used to minimize the energy consumption of a facility to ensure the optimal and effective energy performance of the buildings. The energy management tools simulate the energy behaviour of a facility in the long run [8].

7D BIM: The literature does not draw a tight boundary around 6D and 7D. Further elaboration on the associated tools indicates that 7D BIM includes more lifecycle-related information necessary for achieving energy efficiency and sustainability throughout the lifecycle. Any information which is important for the operation and maintenance of the facility from design to demolition is integrated into 6D BIM to constitute 7D BIM. The information includes asset attributes, operation and maintenance details during the project commissioning period, specifications for the facility, installation and warranty details, maintenance schedules, manuals, and configurations of the equipment that are necessary for optimal performance. Owners can use such information for optimizing the operation and maintenance of the infrastructure towards achieving sustainability objectives. The 7D BIM helps managers visualize the lifetime cost of facilities and make informed decisions considering all lifetime impacts of their decisions on the development or changes in the facility. The lifecycle information is used to enable designers to consider the Total Cost of Ownership (TCO) in infrastructure planning [4].

8D BIM: The eighth dimension of BIM deals with the integration of onsite health and safety requirements into 7D BIM to ensure the safety of all personnel both during the stages of construction and the operation of the facility. This dimension enables managers to interact with the stakeholders and communicate seamlessly to execute safety plans from early stages in the facility lifecycle. Engineering designers could anticipate all preventive actions and key components in the design of the facility so that safety risks are minimized. This dimension aims to prevent accidents and design-related safety issues early in the planning and design phase. However, this aspect of the BIM systems has not been fully implemented in practice, and still, more effective tools and software are needed to perform this integration. 8D BIM could detect and eliminate the safety risk through visual analysis of the facility and its components [3].

9D BIM: The integration of lean construction requirements into 8D BIM forms the 9D BIM as a robust potential tool for more effective delivery and operation of a facility with the optimal use of resources and capital [1]. This dimension emphasizes the resource management techniques to improve the allocation and use of materials, labour, equipment, and tools during the facility lifespan. 9D BIM analyses all resources involved in the process of constructing and operating infrastructure. For example, useful insights can be gained for optimal use of trucks for the transport of materials, reducing the number of onsite vehicles and circulation roads, eliminating repetitive non-value adding tasks, and reducing cycle time.

10D BIM: The 10D BIM is another prospective dimension of the BIM system that aims to take the advantage of industrialized construction and incorporates disaster management plans [1]. This dimension identifies and eliminates obstacles to productivity throughout the design, construction, and delivery of a facility. To improve the productivity level, this dimension encourages the use of drones and manufacturing machines. Artificial intelligence plays an important role in this domain to automate engineering planning and control procedures. This dimension has been introduced recently and its application is yet to be further explored and tested. Incorporating a higher level of automation and systematic control into infrastructure construction increases the rigour of this process and minimizes the harmful impacts on the environment by employing instant information management.

2.2 Success factors for the implementation of BIM

Former research has put forward several success factors for the implementation of BIM in the infrastructure construction sector. These factors range from management commitment to data validation. A literature review on the important factors that lead to the better establishment of this system in organizations introduces the factors in Table 1. Two types of factors affect the implementation of the BIM system in organizations, which include (1) technical factors such as predictive design analysis and simulations, as well as (2) managerial factors such as effective leadership.

Table 1: The main contributions of the BIM system

Success factors for BIM implementation		Dimensions	References
Technical	Accurate 3D visualization of design	3D	[14]
	Appropriate information technology infrastructure	1D to 10D	[15]
	Consistency of design across disciplines	1D to 10D	[16]
	Predictive analysis of the performance of a facility	7D	[14, 17]
	Conducting the thermal energy analysis of the facility	6D	[18]
	Predictive analysis of the environmental impacts	6D and 7D	[19]
	Synchronization of procurement with design specifications	5D to 10D	[14]
	Qualified technical staff to establish BIM	1D to 10D	[17, 20]
	Validation of the model	3D	[19]
	Reliability of the input data	1D to 10D	[21]
Managerial	Supportive organizational culture	1D to 10D	[22]
	Information and knowledge exchange	1D to 10D	[23]
	Stakeholder engagement and collaboration	1D to 10D	[24]
	Clear policy and objectives in BIM	1D to 10D	[25, 26]
	Effective leadership of the BIM implementation	1D to 10D	[17]
	Allocation of budget to BIM	1D to 10D	[26, 27]

2.3 Information systems needed to implement BIM

Implementation of the BIM system requires prerequisite information systems and software to be in place. Previous studies have examined such prerequisites and discussed their link to BIM dimensions. Project information systems provide a platform for collecting and utilizing performance information, earned value, approved change requests, non-compliance reports, and work inspection requests. Such a system integrates time, cost, scope, and quality information and can provide the BIM system with data for linking them with a 3D model [10]. For example, 4D and 5D BIM need the project schedule and cost baseline to be linked to the elements of the design. Project information systems can supply the necessary information for undertaking such analysis. It is suggested to combine AutoCAD and Microsoft Project for the development of a consolidated database that allows for construction process simulation before commencing the construction work [28]. A thorough analysis of the project cost estimates with regard to design features can significantly help to improve estimates and identify errors. The existence of financial information systems (FIS) and their link to the BIM facilitates the transmission of important financial information such as cash flow forecast to be simulated for the whole timeline of a construction project. The existence of FIS and its link to BIM gives clues to estimators to verify cost estimates and optimize quantity take-offs, which is the basis for better long-term financial planning.

Construction projects have plenty of diverse documents such as contracts, engineering drawings, marking plans, assembly plans, and progress reports, which need to be stored in a secure database. BIM needs to be linked to such databases to share with stakeholders and use the information for data visualization. Document management systems (DMS) allow predesignated users to store or retrieve project documents from a shared database. The existence of DMS and its interoperation with BIM contributes to centrally controlling project documents in a project. Another important system to be in place and link to the BIM system is the safety information system. Incorporating safety information into the visualization of construction models gives insight into hazards and corresponding controls to be considered early in the design phase of an infrastructure construction project. Linking the safety information system and BIM enables undertaking hazard risk analysis and better safety planning [11]. The establishment of the 8D dimension requires that an information system of safety inspection records, safety training, incidents, and injuries be established to store the safety-related information and import them into the BIM system for visualization and analysis [29]. The establishment of safety information systems and provision of necessary safety performance data enables real-time safety reporting, as well as hazard risk analysis, regarding the design features of a facility.

2.4 Previous research on BIM Implementation

Implementation of the Building Information Modelling system is quite challenging considering the multiple modules of this system and their interoperation. A recent study examined the implementation of this system in two case studies including an urban regeneration project, and a healthcare project. The focus of this study was on the disconnections between organizational and project level BIM implementation to usefully inform implementation strategy development. It was found that the implementation of the BIM system improved consultation meetings with the client leading to improvements in design quality. Besides, 3D visualization of the design and project parameters provided an in-depth understanding of the facility. However, it is recommended that more effective implementation strategies need to be in place to take maximum advantage of this system both at the organizational and project level. According to this case study, the organizational-level BIM training system failed to support the project-level requirements in new technology adoption [30]. In another study, the issues related to the implementation of the BIM system in the construction industry were examined. The researchers studied global implementation strategies and asserted the importance of coordinated government support and leadership, the development of national and global BIM standards, legal protocols, BIM certification, and BIM education and training [31].

Other studies also attempted to examine barriers to implementation strategies. Zhou et al. [32] examined the barriers in China and found that global strategies should address insufficient government leadership, organizational issues, legal issues, high cost of application, resistance to change of thinking mode and insufficient external motivation. In another study, these barriers were confirmed and it was asserted that strategies should be adopted to deal with skilled personnel shortage [33]. Furthermore, Ma et al. [34] compared BIM implementation strategies in different countries (China, Singapore, Turkey, and Nigeria) and suggested strategies including clearly defined plans and objectives, training and consultancy, organizational leadership and support, financial support, BIM infrastructure, collaborative design, capabilities and skills, access to information and technical conditions, interoperability of engineering data, clients' advocation, and early adoption of BIM regulation. While most of the previous studies have examined the global implementation strategies, the current study concentrates on the company-level strategies which need to be taken into account for a successful implementation so that both the organization and stakeholders can benefit from its positive outcomes in relation to the process of the design and construction. Besides, a more specific focus on the infrastructure construction sector would benefit the body of knowledge since this sector deal with a high level of design and construction complexities [35]. It is important to differentiate between infrastructure delivery, infrastructure construction, and infrastructure management. The current study focuses on infrastructure which should be closely coordinated with the design to deliver a sustainable facility. Thus, the underlying research question is to identify company-level strategies for the implementation of the BIM system in infrastructure construction projects.

3. Methods

The current research is based upon the theoretical discussions in the literature and includes experts' viewpoints on the contribution of BIM in infrastructure construction. The target population includes project management professionals working in principal construction contracting enterprises in Australia. The case study approach allows an in-depth examination of a situation to delve into details of processes and associated outcomes [36]. As a result of a case study in an infrastructure construction project, six practitioners provided their comments on this application of the BIM system. The suggestions from each expert were documented and reviewed so that an overview of the experts' viewpoints can be provided in the paper. Purposive sampling was conducted to ensure that the selected experts have at least five years of relevant experience in the industry. The selected participants worked in project management positions in the case study organization and had job tenure in delivering infrastructure projects [30].

The experts who participated in this study had more than five years of work experience. Six participants with respectively 21, 18, 16, 12, and eight years of work experience provided their insights about BIM implementation. Their positions in the infrastructure project include project manager, assistant project manager, project planners, information technology officer, and designer (two participants). According to the literature, there is no one-size-fits-all threshold to reach data saturation and it is suggested to continue data collection until no new data is obtained [37]. Applying this principle, the saturation point was reached in the sixth interview. The repetitiveness of the comments of participants compared with those obtained from previous interviews was the trigger to stop the data collection. The questions which were asked from the participants include: (1) what is the main contribution of each BIM dimension to infrastructure construction projects? (2) what are the technical strategies for the effective implementation of the BIM system in infrastructure construction projects? and (3) what are the technical strategies for the effective implementation of the BIM system in infrastructure construction projects?

Interviews with the participants were conducted in 30 minutes and their suggestions on the contribution of the BIM system and effective strategies for its implementation in the infrastructure construction sector were obtained. The semi-structured interviews were transcribed and the key suggestions were documented. A thematic analysis of these descriptive suggestions was conducted as a systematic qualitative methodology that involves an inductive data-driven approach for synthesizing and conceptualizing data [38]. This integrative approach brings related ideas together to form the main theoretical feature of a phenomenon. The open coding method was applied to find meaningful themes in experts' suggestions. The results of the interviews were sent to the participants to confirm and improve the outcomes. This validation process helped to improve the validity and rigour of the case study results. As a result of this process, their perspective on (1) the contribution of the BIM system to better infrastructure construction, as well as, (2) the managerial/technical strategies for a more effective implementation were obtained. The results of these parts of the study have been explained in detail in the next section. The research process is outlined in Figure 2.

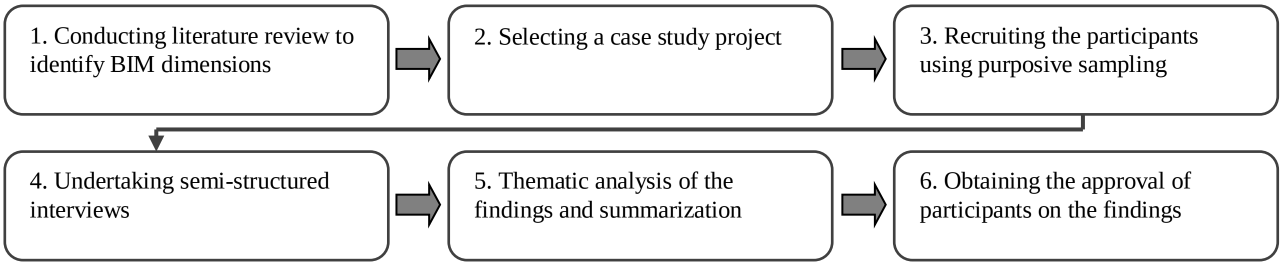

Figure 2: The overview of the research process

4. Results

4.1. The contribution of the BIM dimensions to infrastructure construction projects

The first part of the results is to answer how each dimension of the BIM system can improve the process and outcomes of infrastructure construction projects. Although BIM has application to both the construction and management of infrastructure, the present study focused on the construction stage by undertaking a case study of an infrastructure construction project. As a result of the thematic analysis of interviews regarding the first question (as explained in the methods section), the main contribution of each BIM dimension to infrastructure construction projects was identified. Then, in the next section, the results of analysing data obtained from participants' responses to the second and third interview questions about potential implementation strategies are presented.

1D BIM contributes to (1) providing a historical archive of project information and the evolution of drawings over time, (2) sharing information on project requirements and contracts among stakeholders, (3) keeping the record of the last version of documents for further changes and modifications in details, and (4) clarifying the scope of work and requirements that need to be fulfilled at each phase of an infrastructure construction project. 2D BIM enables the basic modelling of a project through CAD drawings. This aspect of BIM (1) improves the flexibility of the design process by enabling designers to change and update the layout easier than paper-based design, (2) save time in producing and keeping a digital record of drawings compare with manual design, (3) eliminates most of the errors which may occur as a result of calculations, and (4) reduce the cost of design compared with manual drawings.

3D BIM as an important aspect of the BIM system helps to (1) minimize design errors and detect clashes more effective than 2D CAD by visualizing three dimensions, (2) incorporate more design-related information from the perspective of each discipline to improve the 3D model from all perspectives, (3) improve the interdisciplinary collaboration of designers and subject-matter experts, (4) attain higher visibility of the design, and (5) convey the scope and details of a building or facility more effectively. 4D BIM is recently used in the construction industry for better error detection and effective task scheduling. The integration of time and 3D allows (1) more efficient sequencing of the construction process, (2) adjustment of a project activity network to follow a reasonable building methodology, (3) modification of the duration as well as the of the lead/lag between tasks by using schedule animation tools, and (4) keeping track of tasks and their progression. Besides, (5) the risk of project delays due to conflicts of execution with the design documents and plans are anticipated and controlled in advance.

5D BIM as an important dimension of the BIM system contributes to (1) accurate estimation of the cost associated with the construction activities, (2) optimization of cash flows and avoiding project liquidity by adjusting the expenditures, (3) development of more cost-effective infrastructure, (4) automatic generation of quantity take-offs, (5) saving time in the cost forecasting process, (6) reduction of the budgetary offshoot, and (7) real-time visualized analysis of changes in project costs. 6D BIM added the energy considerations to 5D and provides multi-platform access to the building information from the perspective of energy consumption. This dimension allows for (1) energy optimization in the operation of a facility, (2) adopting better operational strategies for optimal performance of a facility, (3) incorporating energy estimates at initial stages of design, and (4) building an energy-efficient facility with minimal cost of operation over time.

The 7D BIM aspect contributes to (1) a more effective decision making related to the operation and maintenance of a facility, (2) an impact assessment of design-related decisions on operational aspects of a facility, (3) more rigorous planning for easy replacement and repairs of equipment in a facility, (4) optimized asset management, and (5) Streamlined maintenance process for clients. 8D BIM considers safety in modelling the facility. The integration of safety into the BIM model enables (1) the establishment of emergency plans, (2) the prevention of security issues, (3) implementation of the occupational health and safety standards throughout the stages of delivery and operations, and (4) decrease risks of accidents and safety hazards.

As a prospective aspect of BIM, the ninth dimension incorporates lean construction and contributes to (1) improving the allocation of resources, (2) enhancing the productivity of construction processes, (3) enhancing the structural integrity of the facility, and (4) optimizing the building design and construction methods towards minimizing waste of materials. Full industrialization is the ultimate goal of BIM in the future, which is conceptualized in the 10D BIM framework. This theoretical dimension represents full industrialization in the construction sector that contributes to (1) automating engineering planning and control procedures, (2) applying virtual reality elements in construction processes, (3) real-time monitoring and controlling the operations, and (4) systematically drive continuous improvement of processes.

An analysis of these aspects in terms of their similarities and differences revealed that the contribution of BIM to infrastructure construction can be translated into three groups including (1) integrity and automation, (2) collaboration, and (3) optimization. Table 2 presents the result of analysing the experts' suggestions in these three categories. Participants also asserted that some dimensions of the BIM system are more important during the design and construction of a facility. It was revealed that 4D and 5D BIM are more beneficial to the construction stages due to visualizing the progression of time and cost. Furthermore, 8D BIM significantly contributes to improving safety outcomes by real-time safety reporting and information sharing that constitute a basis for collaborative safety management on construction sites. 9D BIM is also another key dimension of this system that is quite important throughout the project lifecycle by minimizing waste and optimizing resource allocation.

Table 2: The main contributions of the BIM system to infrastructure construction projects

BIM dimension	Contributions		
	(1) Integrity and automation	(2) Collaboration	(3) Optimization
1D BIM	• Providing a digital archive of all project documents • Managing further changes and modifications to documents	• Sharing information on project requirements • Clarifying the scope of work	
2D BIM	• Easier update in the layout • Keeping the record of all versions of drawings		• Error-free design calculations • Reduce the cost of design
3D BIM	• Higher visibility of all aspects	• Multi-discipline feedback on the design • Convey the scope effectively	• Detect clashes
4D BIM	• Adjust the duration and the lead/lag time • Keeping track of tasks	• Prevent conflicts of execution with plans	• More efficient sequencing of tasks • Reflect a more reasonable building methodology
5D BIM	• Automatic generation of quantity take-offs	• Accurate estimation of the cost through the collaboration of design and estimating team	• Prevent project liquidity • Develop cost-effective infrastructure • Reduce budgetary offshoot
6D BIM	• Incorporate energy estimates in the design	• Better operational strategies in relation to all disciplines	• Energy optimization in the operation stage • Building an energy-efficient facility • Minimal cost of operation
7D BIM	• Analyse the impact of design on the operation • Streamlined maintenance process	• Effective collaborative planning of replacement and repairs	• Optimized asset management • Effective operation and maintenance
8D BIM	• Implementing occupational health and safety standards	• Establishment of emergency plans from the perspective of involved teams	• Decrease risks of accidents • Prevention of security issues
9D BIM	• Enhance the structural integrity of the facility	• Enhance the productivity of construction processes in a collaborative way	• Improve resource allocation • Minimize waste of materials
10D BIM	• Apply virtual reality elements • Real-time monitoring and control of all tasks • Automate engineering planning and control		• Continuous improvement of processes

4.2. Technical strategies for effective implementation of the BIM system

Build a strong BIM technical team: The first and foremost necessity for successful implementation of the BIM system in large multi-discipline infrastructure projects is to be equipped with the required technical expertise among the implementation team. A dedicated team with a high level of BIM technical competencies can bring their expertise and experience to minimize the risk of system errors and failure after implementation. This suggested strategy also confirms the finding of the literature on the role of trained and expert staff in better BIM establishment [17, 20]. Technical competencies have been asserted in previous studies as an important element that facilitates the implementation of BIM. Profound technical knowledge of the BIM implementation team benefits the organization in selecting the correct configuration of each module and aligning them with the requirements and needs of projects [34].

Reinforce information technology infrastructure: An important strategy to improve the information technology (IT) infrastructure necessary as a building block for the establishment of the BIM system. Linking all subsystems and technologies within an organization would benefit better BIM implementation, which enables synchronization of the design, procurement, and construction [14]. Investment in information technology infrastructure helps an organization provide tools and gadgets facilitating the flow of information throughout an organization, as well as between an organization and its stakeholders. Comprehensive information technology needs assessment before starting the BIM implementation would be useful in identifying gaps in IT infrastructure and potential issues which may hinder the implementation process. Adequate information systems, monitoring dashboards, scheduling and estimating software are to be supplied and well established throughout a project [39].

Conduct pilot test: Starting the setup process on a small scale assists the implementation team to capture early feedback and address technical issues in workflows and tools. The implementation team closely tests the process and outcomes of the BIM in the pilot implementation stage to avoid the recurrence of issues on a large scale which would impose higher operational costs. Pilot setup is also acknowledged as a key strategy in the implementation of information systems in general [40], which is also applicable to the implementation of the BIM system. Pilot testing improves the system reliability by detecting and rectifying errors in the modules of the system before the implementation in full scale. The interaction of the BIM system with enterprise systems and databases is also tested during the pilot stage so that the implementation team can ensure the adequacy and quality of input data for 3D simulation and visualization.

Introduce mobile applications: Regarding the ever-increasing use of mobile applications in the construction industry, they are becoming more and more prevalent among companies due to their accessibility and convenience for users [41]. They provide effective tools for more convenient and instant access of decision-makers to the BIM system. Such tools improve agility in the BIM system and, therefore, should be considered early in the design stage by the implementation team as a robust tool. Nourbakhsh et al. [42] developed a mobile application prototype for on-site information management in the construction industry. They demonstrated that mobile applications can be used as a user-friendly tool to manage on-site information generated by involved parties in the construction process. Participants of this study explained that developing simple and functional mobile applications enables instant transmission of information and more convenient access of all the users of the BIM system.

4.3. Managerial strategies for effective implementation of the BIM system

Develop implementation roadmap: The implementation plan is part of establishing BIM in companies [43]. However, a more comprehensive plan is needed to map out all phases of future development and the approach for implementing them. Roadmaps outline not only the establishment of subsystems but also should include future upgrading and evolution of the BIM system to achieve the ultimate target of this system, which is total industrialization of the construction sector. The development of such a roadmap clarify the main stages for the implementation of each dimension of the BIM system. Project leaders may decide to start with limited modules of the BIM system and gradually expand the scope of this system to mechanize processes [44]. System requirements and required infrastructure for making a transition between implementation phases are of crucial significance to prevent errors and provide resources necessary for the implementation of each BIM dimension.

Identify and engage stakeholders: The establishment of any management mechanisms without adequate consideration of stakeholders becomes a challenging task. A complex network of stakeholders may be affected or affect BIM outcomes in large infrastructure projects and even during the commissioning and operations stages. Such stakeholders and their expectations should be identified to seek their buy-in and approval. It is an effective strategy to reduce the risk of low participation and organizational resistance. Although previous research has acknowledged stakeholder engagement as an important success factor of the BIM system, this study asserted that it is vital to focus on identifying all key stakeholders and analysing their interests before deciding on appropriate engagement strategies [24].

Assign dedicated monitoring and coordination team: Previous studies pointed to the importance of trained experts for the proper implementation of the BIM system. While the experts who participated in this research suggested that a dedicated team should be allocated to keep track of the implementation process and undertake the coordination of modules and subsystems in collaboration with the core BIM implementation team. This aspect of implementation has not been mentioned in previous studies and needs to be considered for a more integrated implementation of all sub-systems. BIM has the capacity to reduce clashes through 3D design coordination if the data is supplied timely and correctly [45]. Dedicating a team to ensure appropriate information exchange and coordination of modules would help to establish the inter-module and inter-system links with a minimum risk of misinterpretations and data inaccuracy (Figure 3).

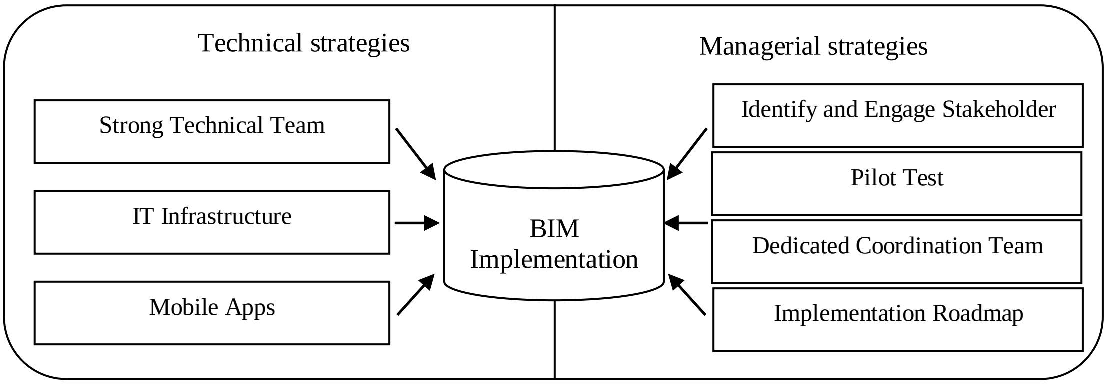

Figure 3: Technical and managerial strategies for more effective implementation of the BIM system

5. Discussion

5.1. The implications of the study

From the theoretical perspective, the present study contributes to a better understanding of the BIM dimensions and their contribution to better infrastructure construction. The three categories of BIM contributions are interrelated and form a value chain leading to better outcomes from the implementation of this information system. First, the basic and underpinning contribution of BIM as a robust information system is to digitalize documents and mechanize processes as a basis for better management of records and control of configurations. The specifications are stored in a secure database and can be used for further reference or change analysis. This category of BIM contributions refers to managing the interfaces between different subsystems concerning all involved teams such as architectural designers, engineering designers, health and safety experts, waste management practitioners, estimators, energy analysts, and project planners. This finding confirms this view that BIM plays a prominent role in the visualization [1] and acts as an integrating platform for other design, construction, operation, and maintenance systems [16].

Second, all teams of subject-matter specialists can collaborate effectively and share their knowledge to accomplish their tasks more productively. Instant sharing of information improves the agility of interdisciplinary decisions and even integrates design-to-demolition operations. Tasks and action plans are synchronized, which pave the way for the coordination of designers, planners, and contractors during the delivery stages. The subsystems interoperate seamlessly based on integrated data to nurture the synergy of subject-matter professionals. As asserted in previous studies, BIM is a means of communication among stakeholders to decrease the risk of miscommunication or conflicts between different aspects of a facility [24].

Third, collaboration encourages innovation and better problem solving as a result of encouraging experts in bringing new ideas and share their best practices. The effective use of visualization and analytical tools coupled with this coordination leads to higher levels of productivity in resources. BIM tools can be applied to analyse inputs from different disciplines to detect errors in design and plans. Major risks of conflicts are identified and control so that as a prerequisite of smooth construction. This aspect of contribution posits that optimization of the energy consumption [8], design features [6], delivery schedule [9], and sustainability characteristics [18] can be achieved through proper implementation and application of BIM in the construction industry (Figure 4).

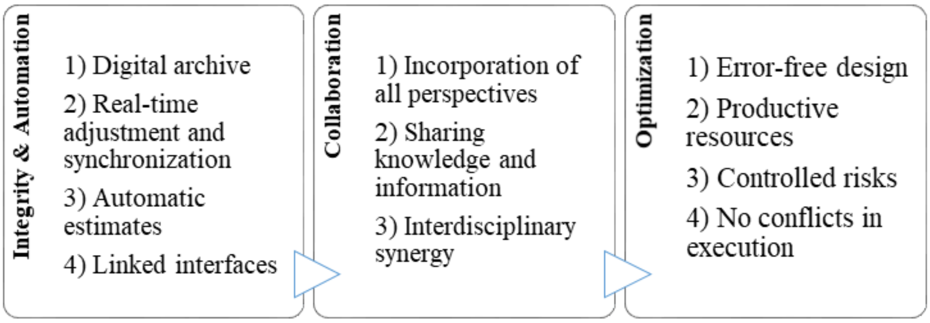

Figure 4: The value chain of BIM

As the empirical implication, the current study reflected on the suggestions of industry experts and introduced technical and managerial strategies for better implementation of the BIM system in the infrastructure development sector. The category of technical strategies aims to enhance the effective establishment of tools, plugins, platforms, and modules to ensure interoperability and synchronization of all components of the BIM system. On the other hand, the managerial strategies focus on enablers in an organizational context that should be properly leveraged to minimize resistance to change and engage stakeholders for a smooth implementation of the BIM section in infrastructure construction projects.

5.2. The limitations and future research

This work is limited due to its theoretical approach reflecting on experts' opinions, indicating that there is a need to validate the outcomes through further empirical research. BIM systems have a variety of applications and can be applied in contexts other than the infrastructure sector. We encourage future studies to undertake a survey or case study analysis to examine the application, benefits, and impacts of the BIM system. This study is also limited since it adopted a universal perspective and discussed all ten aspects of BIM. Thus, future studies can elaborate on a specific dimension of BIM and explore its application and requirements. Another line of potential research on the topic would be to develop a structural equation model of success factors for the BIM implementation. In this regard, the success factors which were synthesized from the literature can be further developed, validated, and tested using statistical analysis tools.

6. Conclusion

The purpose of the present paper was to provide insight into the dimensions of the Building Information Modelling system from a theoretical perspective and introduce effective strategies for their implementation. The view of experts in a case study was reflected to highlight the contributions of the BIM system and introduce effective strategies to implement it. This study posited that there are ten main dimensions of the BIM system that are complementary to each other and map out the evolution of this approach over recent years, which is still under development. These dimensions showed that BIM simulates important technical aspects of a facility from the perspective of three geometrical dimensions of a building. These aspects include time (4D), cost (5D), energy (6D), sustainability (7D), safety (8D), lean construction (9D), and industrialized construction (10D). The integration of the technical specifications of a facility through the lenses of these domains enables adjusting designs and plans to optimize the ultimate project deliverable. It was found that 4D, 5D, 8D, and 9D BIM are more important during the design and construction stages.

The thematic analysis of interviews indicated that three categories represent the contribution of the BIM system to infrastructure construction. This system provides a basis for the automation of workflows. Achieving integrity at the process level ensures that process assets such as procedures and routines are in order and in a complete form to enable a smooth flow of information and decisions across the departments and technical teams. Establishment of tools and information systems under the umbrella of a centralized platform help to automate procedures and minimize the delays and waiting time in different project tasks. It was found that integrity and automation are prerequisites of a collaborative approach in infrastructure construction since without such integration of interfaces the technical specifications of a facility are not being fully captured to be considered in all stages of the engineering design. In light of integrity as well as collaboration, construction practices and outcomes are optimized and errors are eliminated. As another part of the findings, the BIM system can be implemented more effectively by focusing on technical and managerial strategies. While technical strategies improve the foundation and components of such a system, the managerial strategies target resources and support that should be sought towards facilitating the implementation process.

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Information systems project management success

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Abstract:
This paper aims to provide new insights into information systems (IS) project management success. Even though many studies found in the literature show results of software development projects, few studies address the success of IS (socio-technical) projects. Responses to an international survey, regarding 472 projects in total, showed that IS project management is achieving high levels of success; yet, only a minority of projects end without changes in scope, schedule or cost. Furthermore, the results show that changes in scope, schedule or cost are frequent in this kind of project and do not significantly affect the perception of success. These results provide researchers and practitioners with a better understanding of IS project management success evaluation.

Keywords:
information systems; information technology; project; project management; success; criteria; evaluation.

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1. Introduction

Project management success has been a hot topic in the scientific and practitioner literature for a long time [1-4]. However, it has been frequently reported and assumed that Information Systems (IS) projects show low levels of success [5-7]; some of the causes underlying such underachievement are [8]: project underestimation of resources; inadequate definition of requirements; changes in scope; failure to assess, control or manage risks throughout project execution; unrealistic expectations; inappropriate methodology, etc.

Even though there are well-known studies — for instance, the Standish Group's Chaos Reports [9, 10] — that show low levels of success, they typically focus on software development (technical) projects rather than on organizational IS (socio-technical) projects. Although these projects are often treated indiscriminately in the literature, it is important to differentiate them due to the specificities of organizational IS projects' activities, outputs, and outcomes (e.g., changes in business processes), which need to be considered in project management.

A primary goal of software development projects is to create Information Technology (IT) artefacts (e.g., software applications), which are typically mainly technical endeavors. Organizational IS have a different scope. An IS is a combination of intelligent agents (human and/or artificial), processes, and IT (hardware, software, and infrastructure) related to the dissemination and use of data, information, and knowledge in an organization. Accordingly, an IS project can be defined as a temporary endeavor undertaken to improve an organizational IS. In this sense, additionally to projects focused on software development (e.g., a project focused on developing a new digital game), in our study we assume that IS projects have implicit organizational interventions (such as the deployment of a commercial off-the-shelf application), which include placing IT artefacts in organizations — considering both social and technological aspects — where change management has a crucial role.

Even though many studies in the literature report on software development projects' results, few studies specifically address organizational IS (socio-technical) projects. In light of this, some interesting questions can be posed: Is the success achieved in IS project management similar to the success of software development projects? Is project management success of IS projects rigidly tied to fulfilling its scope, schedule, and cost baselines? Do changes in scope, schedule, and cost influence the overall perception on IS project management success?

This research addresses these questions by examining the project management success of IS projects, based on data from an international survey delivered to experienced IS project managers. Our study complements existing research by providing practitioners and researchers with new insights on project management success.

The paper is organized as follows. The following section summarizes the relevant literature on IS projects and project management success. The research design and methodology are described next. Then, the key findings and results are presented and discussed. Finally, we conclude with implications from this study for practice and research, limitations, and some highlights for further research.

2. Background

2.1 Information Systems Projects

Modern organizations face increasing complexity due to their business environment's higher volatility, uncertainty, and ambiguity [9]. In this context, IS play a central role in organizations and are present in almost every aspect of the business [10], being a business core asset essential to improve productivity, reduce operational costs, or gain competitive advantages.

In a rapidly changing business and technological environment, the ability to improve IS is an important aspect that can differentiate organizations from each other. Moreover, organizations must continuously innovate, and an organization's sustainable success is inextricably associated with the success of its IS projects [11].

Companies currently use IS to support their activities at all management levels, and few of them try to conduct their businesses without seeking to exploit the advantages provided by IS. With the increasing complexity of organizations, projects are also becoming more complex [12]. Currently, an IS project can assume many sizes and forms, including implementation of ERP (Enterprise Resource Planning system), CRM (Customer Relationship Management system), SCM (Supply Chain Management system), BI (Business Intelligence system), and ERP modules. IS projects also include custom systems development, systems improvement, process improvement using IT, systems migration, infrastructure enhancement, consultancy, and others [13]. The development/implementation type can vary from customized development to COTS (commercial off-the-shelf)/packaged software implementation.

Even though an IS project can include software development, our study makes a primary distinction by positing that organizational IS projects have implicit organizational interventions thus requiring a socio-technical approach [14].

2.2 Project Success and Project Management Success

The complexity and ambiguity surrounding the definition and measurement of project success [15, 16] have been recognized as a problem since awareness of success has evolved [17]. This is due, for instance, to potentially different perspectives on success by project stakeholders [18].

Two distinct components of project success can be considered [19]: Project Management (PM) success; and the success of project deliverables. The two components are differentiated as follows. PM success focuses on the management process and mainly on the project's successful realization regarding scope, schedule, and cost. These three dimensions indicate the degree of efficiency and effectiveness of project execution. The success of deliverables focuses mainly on the effects of the project's resulting products and services in the post-project stage.

Even though success of PM and success of deliverables are not mutually dependent, unsuccessful PM may jeopardize the success of deliverables. Therefore, the project and its resulting outputs cannot be viewed isolated [20]. Typically, reports on success found in the literature are mainly focused on PM success.

In the case of software development, the projects have not been synonymous with "success" in the last decades [21]. In fact, the software development area often seems to be captive of its failures [22], and this perception is widespread [16]. The Standish Group reports are a landmark in the development of this vision of "failure." This entity has published the first "Chaos Report" in 1994 [23] and, despite the study focused on software development projects, the truth is that the reported results were extrapolated to IS projects in general. Over time, with the periodic publication of the reports, the idea has persisted that projects are problematic and that the levels of failure continue practically unchanged, leading to the conclusion that this critical situation is still unravelling [20]. For instance, the Chaos Report 2020 [24] shows that only 31% of projects are successful, 50% are challenged (e.g., fail in scope, schedule, or results), and 19% fail.

Although these studies are often cited [25], several researchers have questioned them [26-28], due, for instance, to misconceptions about the definition of success and failure. Albeit this criticism of the Standish Group, other authors have reported evidence on high levels of project failure — e.g., Jørgensen and Moløkken-Østvold [28], Cuthbertson [29], Yong, et al. [30], and Iriarte and Bayona [7]. Considering that most studies found are related to software development projects, our research addresses the gap in the literature by focusing on the success of IS (socio-technical) project management.

3. Method

Our method involved administering an online survey to IS project managers. The data were analyzed using descriptive and inferential statistics.

3.1 Measurement Instrument

We used a survey instrument (questionnaire) to measure several aspects of IS Project Management success. We asked participants to consider the last three to five projects they had been involved in and to indicate the characteristics, level of success achieved, and compliance with the scope, schedule, and cost verified in each of those selected projects.

All items used a Likert scale. For “scope”, “schedule”, and “cost” we used a similar scale. For instance, the scale regarding scope was as follows: “Scope not fulfilled;” “Scope fulfilled WITH changes to the original plan;” “Scope fulfilled WITHOUT changes to the original plan.” The “level of success” was measured using a bipolar semantic differential continuous line scale. For analysis purposes, the line was divided into eleven equal sections and coded from 0 (“project abandoned”) to 10 (“complete success”).

The context validity of the questionnaire was examined before starting the survey. Two professors of IS and PM, and nine IS project managers pilot-tested the surveys. The results indicated a few minor refinements, which were then made to the final questionnaire.

3.2 Data Collection

Our sample of IS project managers was primarily drawn from the worldwide community of LinkedIn users. A discussion topic with a link to the online survey was posted in several groups of PM and IS. Additionally, follow-up emails were sent to project managers and chief information officers (holding project management duties), with information about the survey and a link. A total of 111 responses were obtained. Since four of the responses were incomplete and unusable, in our analysis we used a final number of 107 complete responses, representing a total of 472 IS projects (each respondent reported three to five projects).

Table 1 summarizes the demographics of the respondents, who consisted mainly of project managers (52.3%) and chief information officers (19.7%), all of them with experience in PM. The majority of respondents are over 40 years old (71.1%) and have more than ten years of experience (58%), whereas 18.7% have more than 20 years of experience. Finally, 93.5% of the respondents indicated that they held graduate or postgraduate degrees.

Table 1. Profile of project manager respondents

	Frequency	**Percent**
Gender		
Male	85	79.4
Female	22	20.6
Age		
27 – 40	32	29.9
41 – 50	48	44.9
> 50	27	25.2
Education		
Undergraduate	7	6.5
Graduate	40	37.4
Postgraduate	60	56.1
Education area		
Informatics	20	18.7
Information Systems	39	36.5
Business Management	27	25.2
Other	21	19.6
Training or certification in project management		
Yes	70	65.4
No	37	34.6

	Frequency	Percent
Current position		
Project manager	56	52.3
Chief Information Officer / IT Director	21	19.7
Director / Manager	15	14.0
Other	15	14.0
Average years in the position		
1 – 10	23	21.5
11 – 20	45	42.1
> 20	39	36.4
Average years in project management		
1 – 5	13	12.1
6 – 10	32	29.9
11 – 20	42	39.3
> 20	20	18.7
Number of projects as project manager		
< 11	25	23.4
11 – 30	42	39.2
> 30	40	37.4

Table 2 summarizes the characteristics of the respondents' companies. The respondents came from organizations of different sizes (small, medium, and large). Many of those companies align their PM methodology with PMBOK (37.4%), while only 12.1% use a PM maturity model to improve their PM practices. The sample is split evenly in several contextual variables (e.g., total employees and turnover), rendering the analysis more reliable. The majority of those companies have headquarters in Europe (62.6%) and North America (23.4%), and an international presence (60.7%). To sum up, the respondents are experienced project managers representing various company sizes and PM approaches.

Table 2. Profile of respondents' companies

	Frequency	Percent
Total employees		
1 – 200	33	30.8
201 – 500	20	18.7
501 – 2000	22	20.6
> 2000	30	28.0
Did not know / Did not answer	2	1.9
Turnover		
< 1.000.000	15	14.0
1.000.000 – 10.000.000	19	17.8
10.000.001 – 250.000.000	24	22.4
> 250.000.000	23	21.5
Did not know / Did not answer	26	24.3
Headquarters		
North America	25	23.4
Europe	67	62.6
Other	15	14.0
Number of countries where it is present		
1	42	39.3
2 – 10	36	33.6
> 10	29	27.1
Certifications		
Yes	50	46.7
No	57	53.3

	Frequency	Percent
Project management approach/methodology		
PMBOK or Custom (based on PMBOK)	40	37.4
Custom (based on various methodologies)	26	24.3
It is not used a formal methodology	22	20.5
Other	19	17.8
Uses a project management maturity model		
Yes	13	12.1
No	94	87.9
Main software used in project management		
MS Project	55	51.4
MS Excel	20	18.7
Custom	13	12.1
Other	19	17.8

3.3 Data Analysis

The data collected through the questionnaire survey were analyzed using the Statistical Package for the Social Sciences (SPSS) software package.

The statistical tests included One-way ANOVA (and Levene's *F* test), Kruskal-Wallis, and Mann-Whitney. These tests were selected considering the number of variables, the type of measurement and number of levels of variables (of the dependent and independent variables), and compliance with statistical assumptions.

One-way ANOVA should be used when the dependent variable is normal/scale data, and the independent variable has three or more levels or groups. The assumptions of the test are: observations are independent; variances on the dependent variable are equal across groups; the dependent variable is normally distributed for each group. Levene's *F* test for the assumption that the variances of the groups are equal.

As nonparametric tests, Kruskal-Wallis and Mann-Whitney were selected when the assumptions for using parametric tests were violated (e.g., normal distribution of variables).

The Kruskal-Wallis test should be used when the dependent variable is clearly ordinal or parametric assumptions are markedly violated, and the independent variable has three or more levels or categories/groups/samples.

The Mann-Whitney test should be used when the dependent variable is clearly ordinal or parametric assumptions are markedly violated, and the independent variable has two levels or categories/groups/samples.

4. Results and discussion

4.1 Information Systems Projects

We asked project managers to characterize the last projects they had participated in. Each of them reported three to five projects, which are summarized in Table 3. They were involved in projects of varying types, costs, and durations. Almost 42% of the projects were related to implementing ERP/CRM systems, 19.3% to the implementation of custom systems, and the remaining to BI implementation, process improvement, and others (e.g., system maintenance). The development/implementation type was mainly customized development (41.9%) and implementation of packaged software/commercial off-the-shelf (COTS) together with customized development (31.6%). Regarding project duration, slightly more than half of the projects (54.1%) lasted up to nine months, and the mode duration of a project was six months. Concerning budget, the reported projects present a wide range of project sizes, including projects with a budget less than 25K EUR to projects with budgets of more than 2M EUR (the majority of projects had a budget of fewer than 250K EUR).

Table 3. Project characteristics

	Frequency	Percent
Project type		
ERP implementation	83	17.6
CRM implementation	37	7.8
BI implementation	44	9.3
ERP module implementation	78	16.5
Custom system implementation	91	19.3
Process improvement	41	8.7
Other	98	20.8
Development/implementation type		
Customized development	198	41.9
Packaged software / COTS	82	17.4
Customized development and packaged software / COTS	149	31.6
Other	43	9.1
Project Duration (in months)		
1 - 3	82	17.4
4 – 6	118	25.0
7 – 9	55	11.7
10 – 12	94	19.9
13 – 24	89	18.9
> 24	34	7.2
Project Budget (in EUR)		
< 25.001	71	15.0
25.001 – 50.000	61	12.9
50.001 – 100.000	63	13.3
100.001 – 250. 000	62	13.1
250.001 – 500.000	57	12.1
500.001 – 2.000.000	70	14.8
> 2.000.000	57	12.1
Did not know / Did not answer	31	6.6

4.2 Information Systems Project Management Success

As shown in Figure 1, IS Project Management is achieving high levels of success, with the majority of projects at the top levels (52.1% of the projects are in the ninth and tenth levels, meaning that the ten is a complete success), and only 16.1% are below level 7. Concerning the projects below the middle point (5), the percentage drops to 7.4%.

These results contradict the general idea regarding IS projects' success. The differences may be due to several reasons. They may be related to the types of projects implemented, or to evaluation criteria and evaluation models used. For instance, the classic definition of success contained in the well-known Standish Group's Chaos Reports is [23]: "The project is completed on-time and on-budget, with all features and functions as initially specified." More recently, project success was redefined by the Standish Group to "on time, on budget, with a satisfactory result" [31] and a project is considered "challenged" if it fails just one criterion.

Figure 2 shows the obtained results regarding accomplishment of scope, cost, and schedule in IS projects. Overall, IS projects are being completed according to the defined scope, schedule, and cost of the surveyed cases, respectively at 94.1% (39.8%+54.3%), 87.5% (37.9%+49.6%), and 89.8% (50%+39.8%). However, in most cases, such accomplishment is not related to the original plan. When considering the initial plan, the results drop to 39.8% in the case of scope, 37.9% in the case of schedule, and 50.0% in the case of cost.

Putting these criteria together, the total number of 123 projects (26.1%), i.e., about one-quarter of the projects, simultaneously fulfilled scope, schedule, and cost without changes to the original plan. This shows that in IS Project Management, fulfillment of scope, schedule, and cost is not rigidly tied to the initial plans.

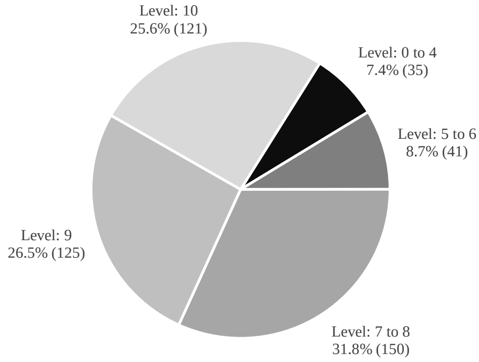

Figure 1. Level of success achieved in IS project management

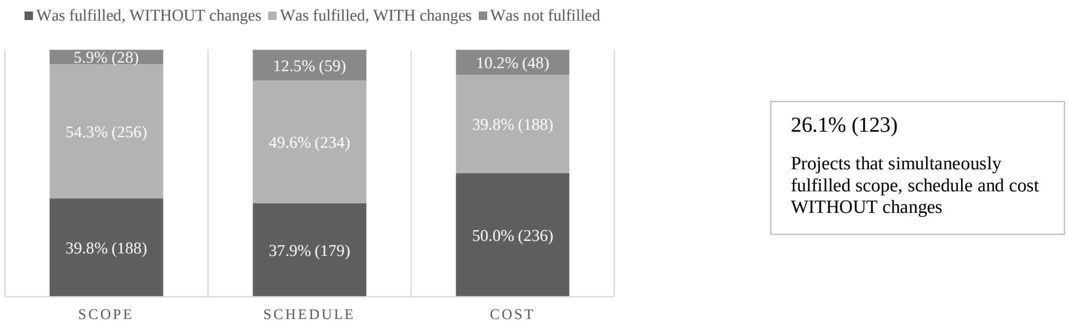

Figure 2. Compliance with Scope, Schedule, and Cost in IS project management

4.3 Information Systems Project Management Success and Fulfillment of Scope, Schedule, and Cost

We tested scope management, time management, and cost management independent variables with the dependent variable project success to analyze if differences in the level of success are related to fulfillment of scope, schedule, and cost (WITH and WITHOUT changes).

We used one-way ANOVA to compare the three levels of *scope management* on the dependent variable *project success*. Levene's *F* test result was $p=0.206$ (not significant), so the assumption was not violated. Since the assumptions were not violated, the ANOVA test could be used. A statistically significant difference was found among the three levels of *scope management* on *project success*, $F(2, 469) = 92.658$, $p<0.001$. The mean *success* is 4.1011 for projects where "the scope was fulfilled WITHOUT changes to the original plan", 3.3555 for projects where "the scope was fulfilled WITH changes to the original plan", and 1.5 for projects where "the scope was not fulfilled".

We used the nonparametric Kruskal-Wallis test to compare the three levels of *schedule management* on the dependent variable *project success* since Levene's *F* test ($p=0.004$) was significant (so the homogeneity of variance assumption was violated). The results (*Chi-Square*=1.754, $p=0.416$) show that there is no overall difference among the three groups of *schedule management*. Nevertheless, the mean rank for projects where "the schedule was fulfilled WITHOUT changes to the original plan" is greater than for projects where "the schedule was fulfilled WITH changes to the original plan" or "the schedule was not fulfilled" (respectively, 8.00, 5.33, and 5.00).

We used one-way ANOVA to compare the three levels of *cost management* on the dependent variable *project success*. Levene's *F* test ($p=0.851$) was not significant, so the assumption was not violated. A statistically significant difference was found among the three levels of *cost management* on *project success*, $F(2, 469) = 83.534$, $p<0.001$. The mean *success* is 3.9746 for projects where "the cost was fulfilled WITHOUT changes to the original plan", 3.4096 for projects where "the cost was fulfilled WITH changes to the original plan", and 1.9375 for projects where "the cost was not fulfilled."

A Mann-Whitney test was used to investigate whether projects where "scope, schedule, and cost were fulfilled WITHOUT changes to the original plan" differ from the other projects regarding achieved success. This nonparametric test was selected since Levene's F test (p=0.009) was significant (so the homogeneity of variance assumption was violated). The results obtained (Mann-Whiney U = 10126, Wilcoxon W = 71201, Z = -9.031, p<0.001) indicate that there is a significant difference between groups. The mean rank for the group "scope, schedule, and cost were fulfilled WITHOUT changes to the original plan" is 328.67 (N=123), and the mean rank for the other group is 204.01 (N=349).

Table 4 presents a summary of the statistical tests' results.

Table 4. Level of success and fulfillment of scope, schedule, and cost

Variables	**Scope**	**Schedule**	**Cost**	**Scope, Schedule, and Cost**
Statistical test	One-way ANOVA	Kruskal-Wallis	One-way ANOVA	Mann-Whitney
Fulfilled WITHOUT changes	4.1011	8.00	3.9746	328.67 (N=123)
Fulfilled WITH changes	3.3555	5.33	3.4096	204.01 (N=349)
Not fulfilled	1.5	5.00	1.9375	
Results	Difference found	Difference not found	Difference found	Difference found
	F (2,469)= 92.658, p<0.001	Chi-Square= 1.754, p=0.416	F (2,469)= 83.534, p<0.001	Mann-Whitney U=10126, Wilcoxon W=71201, Z=-9.031, p<0.001

Additionally, we used one-way ANOVA to compare the levels of *project type* on the dependent variable *project success*. Levene's F test (p=0.298) was not significant, so the assumption was not violated. A statistically significant difference was found among the levels of *project type* on *project success*, F (6, 465) = 2.892, p<0.009. The project types showing a higher mean are "Business Intelligence implementation" (3.7955), "ERP module implementation" (3.6667), and "Other projects" (3.8367). This may be due to the fact that these projects usually have a smaller scope than "ERP implementation" or "CRM implementation". However, further studies are required to explore this result.

4.4 Summary and Discussion of Main Results

Figure 3 presents a summary of the achieved results, answering the underlying research questions. On the one hand, the results show that IS projects are achieving high levels of success, a finding that counters the taken-for-granted assumptions that many IS projects fail. It should be noted that in our study we address organizational IS (socio-technical) projects.

On the other hand, only a small percentage of projects (26.1%) end up fulfilling scope, schedule, and cost without changes to the original plan. It is normal in IS projects to have changes in scope, schedule or cost, so those changes, if justified, do not hinder project management success [4]. This is understandable, since these changes are often due to business vicissitudes during project implementation (i.e., beyond the control of the project) or to the characteristics of projects, which are increasingly organized in an agile way.

Notwithstanding, the projects with higher levels of success are those where scope, schedule or cost is fulfilled without changes to the original plan. Thus, changes in scope or cost may have implications in the levels of success achieved. For instance, even changes well justified and beyond the project manager's responsibility may have negative consequences on program or portfolio management, impacting other projects or business initiatives and ultimately affecting the results.

Comparing these results with the Standish Group's Chaos Report 2020 [24], there are obvious differences, but also similarities. First of all, the idea of success is quite different, since our study shows higher levels of success. However, when taking the Standish Group's definition of success strictly, the results are quite similar (26.1% in our study vs. 29% of successful projects in the Chaos Report 2020).

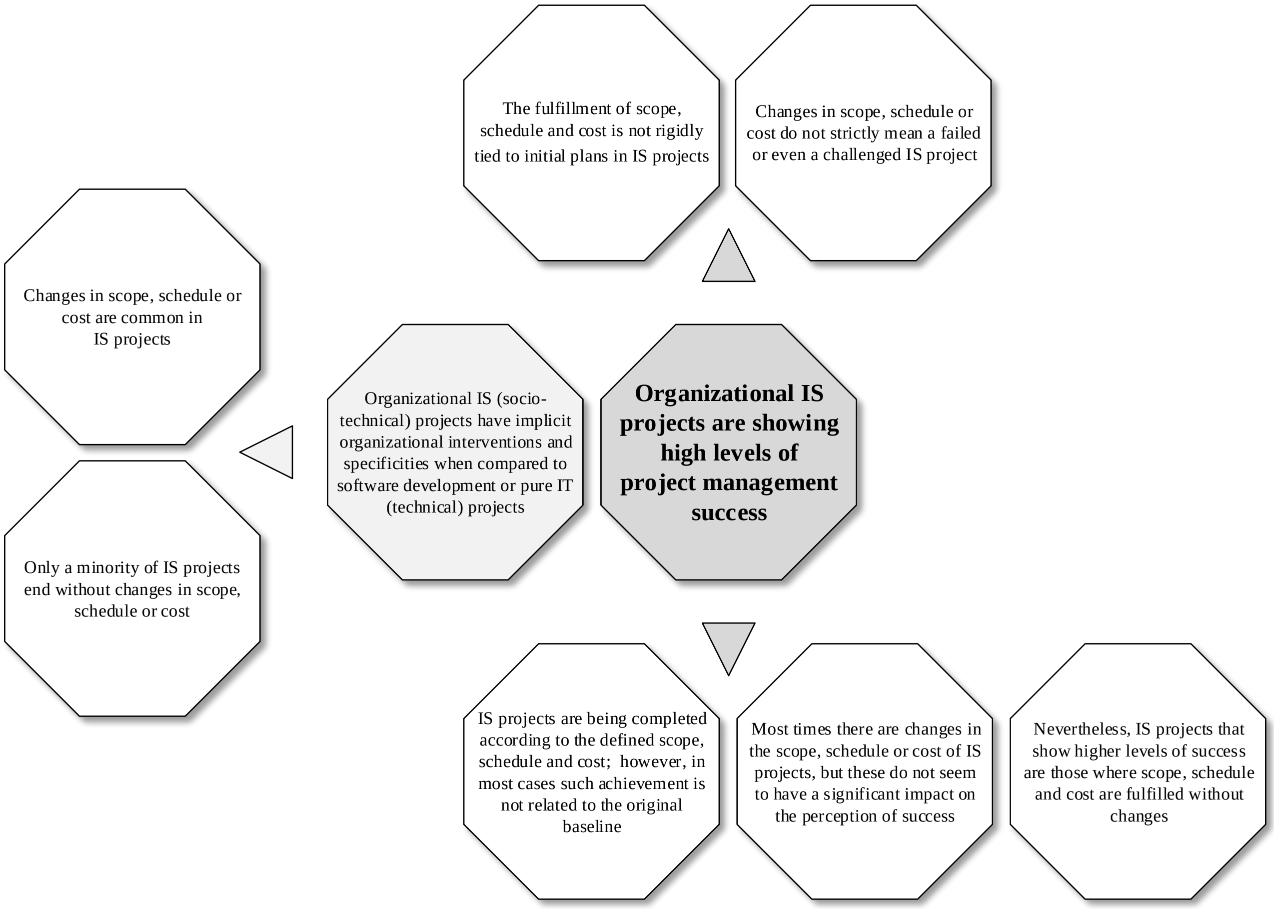

Figure 3. Summary of results

5. Conclusion

This study has significant implications for practice, research, and education, providing new insights into IS Project Management success. The obtained results challenge the general idea that IS projects are "problematic endeavors". On the contrary, organizational IS Project Management is showing high levels of success, and changes in scope, schedule, and cost do not entail a failed or even a *challenged* project, i.e., fulfillment of scope, schedule or cost is not rigidly tied to the original baseline, since the project's targets evolve along the life cycle. Since changes are common and normal in IS projects, project management methodologies should be designed and adopted by taking this into account.

Before discussing directions for future research, it is necessary to point out the limitations of this study. It represents an advance regarding earlier work, but still has some limitations. Similarly to other studies, one such limitation is that it relies on self-reported evidence of recent experiences of project managers. This means that each project that is included in this study relies on the memory of one project manager responsible for the project. It would be interesting to contrast the various stakeholders perceptions (e.g., senior management), since they may have different perspectives on the reported success. Regarding the sample, most participants are from Europe (62.6%) and North America (23.4%). Consequently, the obtained results are relevant in the case of the surveyed companies at the moment of data gathering. Only through further research can the results be generalized (concerning other/all similar projects executed around the world).

One avenue for future research would be to examine in detail the results of IS projects, aiming to answer several new questions that arose from this research: What criteria are being used in IS projects practice to evaluate success besides the traditional “Iron Triangle”? Do these criteria differ from project to project? Since changes in scope, schedule, and cost do not seem to compromise the project’s overall success, how are these changes justified and negotiated with stakeholders? Do some types of projects (e.g., BI projects) show higher levels of success? It would also be an interesting avenue to study the perspectives of several stakeholders regarding success — for instance, to analyze whether the impact of changes on success is perceived similarly by all of them.

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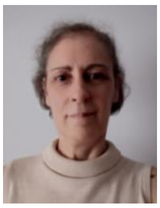

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