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Analyzing the Digital Infrastructure Enabling Project Management Success: A Hybrid FAHP-FTOPSIS Approach

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Abstract: This research paper examines the digital infrastructure required to achieve project management success by analyzing the enabling elements of this digital infrastructure in terms of three pillars: digital readiness, digital fitness, and digital tools. A comprehensive literature review was conducted to identify these enabling elements and to develop a list of project management success indicators through which the success of project management can be measured. To evaluate and rank the digital infrastructure enabling elements, a Multi-Criteria Analysis (MCA) was implemented using a hybrid approach combining Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS). The study used the digital infrastructure enabling elements as MCA alternatives and the project management success indicators identified in the literature review as MCA criteria. The results indicated that the enabling elements associated with digital tools are the most significant for project management success, with a FTOPSIS closeness coefficient (CC_i) of 0.8525, followed by those related to digital fitness (CC_i = 0.6481) and digital readiness (CC_i = 0.1602). These findings have proven to be robust, as they remained consistent even when weights of the MCA criteria were adjusted in three new scenarios proposed in a scenario analysis. This research highlights the critical role of digital enabling elements in enhancing project management practice and achieving project management success. It also offers a strategic framework for organizations to develop and strengthen their digital infrastructure.

Keywords: digital infrastructure; Industry 4.0; digital transformation; Industry 4.0 enabling technologies; digital project management; digital fitness; digital readiness; digital tools; project management success

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1. Introduction

Most organizations are interested in digitalization through the implementation of Industry 4.0, enabling technologies to automate processes and pave the way for digital transformation activities to create new business values [1], positively impacting organization growth, structure of value chains, and nature of work itself [2]. Digitalization also creates new opportunities, improves employment and skills [3], and supports new business models [4]. Additionally, Industry 4.0 and the implementation of its enabling technologies can support the optimization of time and costs, enable adaptation to change and new business models [5], and help organizations gain a competitive advantage through the improvement of innovative and competitive products [6]. Marnewick et al. [7] and Kanski et al. [8] studied the role of Industry 4.0 enabling technologies and digital solutions in project management success. The implementation of Industry 4.0 enabling technologies has prerequisites that can be integrated into the organization to enhance digital readiness, facilitate transformation toward Industry 4.0, and minimize failure risk [9]. The prerequisites for the adoption of digital solutions and the implementation of Industry 4.0 technologies are described in this research with their broad perspective and collective role in project management success under the term "Digital Infrastructure".

One of the generic prerequisites linked to the business strategy in organizations is the continuous improvement process [10]. Having an established business strategy will facilitate the successful implementation of Industry 4.0 enabling technologies and hence empower the decision-making process for project management success. Common prerequisites identified irrespective of the implemented technology are large internet capacity, cyber security systems, Machine to Machine communication, competent employees, access to real-time data, and financial resources [10,11]. Raj et al. [12] highlighted the organizational culture encouraging and supporting technological innovation as a prerequisite for the adoption of Industry 4.0. Furthermore, Marnewick et al. [7] identified four focus areas needed for practitioners in a project organization to establish a digital infrastructure that enables project management digitalization. These focus areas are technology, culture, business models, and theoretical lenses. In this paper, the prerequisites pertaining to Industry 4.0 enabling technologies and their implementation in the organization will represent the first pillar of digital infrastructure and will be referred to as "digital tools". The prerequisites pertaining to the presence and implementation of general technologies in the organization, the adoption of business models, and theoretical lenses will represent the second pillar and will be referred to as "digital readiness". Finally, the prerequisites pertaining to the organizational culture in relation to employees and teams, enabling them to play their roles in properly implementing digital tools in a digitally-ready organization in pursuit of project management success, will represent the third pillar and will be referred to as "digital fitness". Accordingly, digital infrastructure refers in this article to the set of digital tools, combined with digital fitness and readiness required to achieve the project management goals and enable the project management practice towards project management success. Digital infrastructure was defined based on the three aforementioned pillars that represent the three main requirements for an organization to be entirely equipped with the necessary infrastructure for digitalization and Industry 4.0 transformation.

The existing literature has acknowledged the importance of digital infrastructure in project management, but the relationship between digital infrastructure and project management success has only been explored in the context of Industry 4.0 enabling technologies and their implementation. For example, the work of Kanski et al. [8] has filled the research gap pertaining to studying the key components of Industry 4.0 determining project success, while the work of Marnewick et al. [7] aimed to develop a link between project management and digitalization, defining digitalization as the integration of various technologies into all aspects of a work environment. There is a scarcity of research that systematically breaks down digital infrastructure into enabling elements and analyzes these elements through a structured MCA. Therefore, this research aims to fill this gap by addressing the lack of a comprehensive evaluation and ranking analysis that identifies, categorizes, and ranks the enabling elements of digital infrastructure critical to project management success. To address the aim of this article, the following research objectives are identified:

1. Defining the digital infrastructure in terms of three pillars and identifying specific enabling elements for each pillar;
2. Providing a methodologically rigorous evaluation and ranking of the enabling elements in terms of their effect on project management success, using advanced MCA techniques (FAHP and FTOPSIS), offering a clear prioritization that guides organizations on where to focus their digital efforts for maximum impact on project management success;
3. Testing the robustness of the MCA findings across various scenarios, which addresses the gap in understanding how changes in the weights of project management success criteria (indicators) might influence the importance of the digital infrastructure enabling elements, offering insights into the stability and generalizability of the findings.

This article links project management success with the prerequisites of digitalization and implementation of Industry 4.0 enabling technologies. This linkage is done through the development of an MCA that aims to weigh and rank the enabling elements of the implementation of the prerequisites to achieve project management success. A hybrid approach of FAHP and FTOPSIS is used in the MCA in the methodology of this research. The Analytic Hierarchy Process (AHP) will also be integrated to exclude the criteria with low importance and to eventually reduce the number of criteria from 11 to 7. A scenario analysis is also conducted at the end of the study after adjusting the weights of the criteria used in the analysis. Hence, this article aims to answer the following questions:

1. What are the enabling elements of each digital infrastructure that contribute to project management success?
2. How can these elements be ranked in terms of their impact?
3. How robust are the enabling elements of digital infrastructure when assessed under different scenarios, and do their rankings change when the weights of the project management success indicators (criteria) are adjusted?

2. Literature Review

2.1. Pillars of Digital Infrastructure

2.1.1. Digital Readiness

Weiner [13] views readiness in its generic definition as a sense that is developed in an organization by collective engagement, leadership commitment, information sharing and collaboration, organizational culture, organization policies, and situational analysis. According to Lokuge et al. [14], the lack of digital organizational readiness is standing in the way of organizations in their pursuit to achieve digital transformation. Lokuge et al. [14] described digital readiness as the level of willingness and preparedness in an organization to adopt, perceive, and exploit digital technologies. De Sousa Jabbour et al. [11] found that a critical factor in ensuring success and competitiveness in Industry 4.0 is organizational change readiness, entailing digital readiness.

According to Machado et al. [15], the level of digitalization in an organization can be better aligned with the organization's business strategy when its digital foundation is developed and improved. According to Tortorella et al. [16], the implementation of Industry 4.0 technologies is assessed through maturity models such as the one proposed by the German government based on 9-dimensional items, most of which are related to managerial aspects of the organization like strategy, leadership, people, and governance. Machado et al. [15] further investigated maturity levels in an organization and identified three maturity levels: organizational maturity, digital maturity, and smart maturity. Digital readiness is highlighted as the first level of the maturity framework developed to describe the stage in which an organization has developed the required digital connectivity and infrastructure to adopt cyber-physical systems. Digital maturity is achieved by defining a digital agenda, developing a digital strategy and a digital ecosystem, activating digital monitoring, improving collaboration, considering the perspective of transformation, enforcing vertical and horizontal integration, adopting full organization-wide digitalization, and expanding IT systems support. Digital maturity is defined by five main dimensions: organization and governance, digital strategy and business model, connectivity and IT infrastructure, manufacturing systems and technology, and data collection and analytics. Subdimensions of digital maturity identified by [15] include digital strategy, digital ecosystem, connectivity, cyber-security, data processing, system architecture, digital twin, big data, and data management and governance. According to Genest et al. [10] and de Sousa Jabbour et al. [11], Machine-to-Machine communication, competent employees, access to real-time data, and financial resources are prerequisites to the successful implementation of digital solutions and Industry 4.0 enabling technologies towards project management success, irrespective of the implemented technology.

Digital readiness is also defined by digital culture, which is highlighted in the same article as an enabler on the roadmap to achieving smart organizational maturity. Geissbauer et al. [17] state that an organization has to start by the assessment of its digital situation and capabilities and the identification of its technological and organizational adjustments in order to pave the road for digital organizational readiness. A model was developed to highlight digital readiness obstacles such as lack of knowledge of digitalization and its benefits and threats, lack of digitally skilled employees, and lack of digital corporate culture [18]. These obstacles can be addressed by the availability of financial means, digital skills, standards, and legal frameworks. Other ways and frameworks were suggested to support overcoming digital readiness obstacles by institutionalizing new technologies and processes in the organization in addition to achieving fundamental business changes [11].

According to Elhusseiny et al. [19] and Luthra et al. [20], the adoption of Industry 4.0 technologies has four main barriers divided into four main categories: technical barriers, organizational barriers, technological barriers, and legal barriers. Establishing an organizational infrastructure that addresses each one of these barriers can effectively improve the adoption process of Industry 4.0 technologies. The technological/IT infrastructure can address technological barriers as it is considered one of the five dimensions defining digital maturity [15]. Ranadive et al. [21] state that IT supports an organization by enhancing processes and systems automation, improving data collection, and reengineering traditional working systems to enable and support project management success. Legal barriers can be addressed by a robust legal infrastructure in the organization to overcome obstacles preventing digital organizational readiness through the availability of legal norms, standards, and frameworks [18]. The social factors are also of high importance when considering the adoption of Industry 4.0 [22]. The social barriers hindering the implementation of Industry 4.0 and its enabling technologies in an organization include the fear of employees losing their jobs or being replaced and employees lacking the know-how competencies and IT-related competencies. These social barriers can be considered as steppingstones which can be addressed with a well-structured social infrastructure to develop a digitally ready organization in pursuit of the implementation of Industry 4.0 enabling technologies towards project management success. Moreover, a robust ICT infrastructure in an organization can support project operations [23] by improving coordination, collaboration, cooperation, and communication between project team members [24]. Eliwa et al. [25] conducted an empirical study that concluded that an important enabler in enhancing project outcomes, improving the final project performance, and facilitating project delivery is the alignment between an organization's ICT infrastructure, ICT utilization, and ICT implementation.

Other researchers highlighted other less significant barriers to Industry 4.0 implementation, such as data ownership concerns as a result of big data use, the lack of know-how of employees, the courage of top management to implement Industry 4.0 technologies [26], and security and privacy issues [27]. In conclusion, the following enablers were deduced to represent the enabling elements of digital readiness as a pillar of digital infrastructure, as shown in Table 1.

Table 1. Enabling elements of Digital Readiness as a pillar of digital infrastructure.

Enabler of Digital Readiness	Code	Description	Reference
Cybersecurity Systems	DR1	Digital Readiness Enabling Element 1	[15]
Real-time Data Access and Management	DR2	Digital Readiness Enabling Element 2	[11]
Technological Infrastructure	DR3	Digital Readiness Enabling Element 3	[19]
Large Internet Network Capacity	DR4	Digital Readiness Enabling Element 4	[10]
Social Infrastructure	DR5	Digital Readiness Enabling Element 5	[22]
Legal & Ethical Infrastructure	DR6	Digital Readiness Enabling Element 6	[20,28]
ICT Infrastructure	DR7	Digital Readiness Enabling Element 7	[23]

2.1.2. Digital Tools

Digital tools were defined in this article as the pillar of digital infrastructure pertaining to the enabling technologies of Industry 4.0 and the series of cultural and technological shifts achieved in an organization as a result of the implementation of these technologies. Industry 4.0 enabling technologies are the digital technologies that support an organization in reaching certain levels of digitization and digitalization that will lead to a complete digital transformation of the organization [29]. On the other hand, digital transformation is the highest level of digital maturity witnessed in an organization as a series of deep and coordinated strategic, cultural, and technological shifts toward new business value creation [1]. Accordingly, based on these two components, the enabling elements of digital tools were identified as digital transformation and Industry 4.0 enabling technologies. The implementation of Industry 4.0 enabling technologies helps the company in adopting processes with higher speed and flexibility through the integration of intelligent applications and adaptive services [30]. The digital transformation element is about the utilization of digital technologies, resources, and capabilities to expect economically driven outcomes such as cost reduction and error elimination or capability-driven outcomes such as enhancing innovation and creating innovation cultures with competitive advantage [31].

- Industry 4.0 Enabling Technologies as an Enabling Element of Digital Tools

According to Elhusseiny et al. [19], the implementation of Industry 4.0 technologies can be through horizontal and vertical IT integration, whereby the horizontal integration of Industry 4.0 enabling technologies facilitates the interaction and management between the supply chain members in a way that improves business and operational performance, and decision-making. On the other hand, vertical integration leads to improved quality, planning, and reduced cost and waste. This indicates that the two types of integration have a positive effect on project management success indicators, as also supported in the conclusion of the paper, which states that the horizontal and vertical integration of Industry 4.0 enabling technologies improves management aspects in an organization as well as organizational performance, leading to the conclusion that the relationship between Industry 4.0 implementation and management is reciprocally positive. According to Aoun et al. [26], blockchain plays an important role as a driver for most other Industry 4.0 enabling technologies, as it can provide solutions that are able to simplify business models and processes, decrease costs, and increase productivity, flexibility, and system efficiency. Additionally, Artificial Intelligence (AI) has been, in recent years, increasingly used in different applications of project management to optimize project schedules, prepare financial reports, integrate datasets, allocate resources, and find new resources in a manner that helps reduce the time spent on administrative work, improve time estimation of project tasks, and easily monitor budgets and schedules, for the purpose of improving collaboration between project team members, and building trust between project stakeholders [32]. AI can improve project performance through faster data analysis, leading to the elimination of 80% of the project management work. Collins [32] also highlights the role of big data in supporting project management success by predicting project tasks and their times, optimizing resources, automating processes, and minimizing human efforts.

Digital Transformation as an Enabling Element of Digital Tools

Digital transformation is the utilization of digital technologies, resources, and capabilities to expect economically driven outcomes, such as cost reduction and error elimination, or capability-driven outcomes, such as enhancing innovation and creating innovation cultures with competitive advantage [31]. According to Verhoef et al. [33], digital transformation is defined in three different stages: digitization, digitalization, and digital transformation. Abdallah et al. [1] state that digitalization is the step that precedes digital transformation in an organization, as it automates processes by means of Industry 4.0 technologies in a way that lays the basis for digital transformation across the organization. Marnewick et al. [7] addressed the role of digitalization in project management by emphasizing that it is changing how projects are managed as well as the very nature of project management.

As for the digital technologies implemented as part of the digital transformation process, these technologies have changed the way industries run their business [34]. For instance, digital technologies are now shifting their focus to meeting the needs of their clients and improving the value of their products in the market instead of maximizing their profit. According to Wang et al. [35], digital transformation can drive business performance, supported by its associated digital technologies, such as big data, mobile applications, and social networks. Smart technologies are considered a digital transformation tool that can generate improved organizational performance [36]. According to Hansen et al. [37], digital technologies have a significant effect on the management of organizations within the socio-economic context. Therefore, digital technologies can be conceptualized to benefit from their virtual dynamics and enable the implementation of smart management.

Tortorella et al. [16] indicated that digital transformation and its successful related initiatives lead to improved and sustainable performance. Moreover, enabling digital transformation allows the company to create new market-flexible processes, leading to structural changes in the organization and value creation [38]. According to Papadonikolaki et al. [39], digital transformation has caused a shift that "carries profound implications for project management, necessitating a re-evaluation of traditional approaches and an emphasis on integrating digitalization in project management practices to cope with dynamic environments, control performance and enhance their capabilities". Overall, existing research on digital transformation in projects has been primarily focused on what technologies can help organizations and people achieve aside from improvements in organizational performance and project management practices [40], which adds to the value of this research as it contributes to its originality in addressing the role of digital transformation as an enabling element for one of the pillars of digital infrastructure. The following enablers shown in Table 2 were deduced to represent the enabling elements of digital tools as a pillar of digital infrastructure 2.

Table 2. Enabling elements of Digital Tools as a pillar of digital infrastructure.

Enabler of Digital Tools	Code	Description	References
Digital Transformation	DT1	Digital Tools Enabling Element 1	[35,36,40]
Industry 4.0 Enabling Elements	DT2	Digital Tools Enabling Element 2	[26,32]

2.1.3. Digital Fitness

According to Guinan et al. [41], the success of digital transformation is dependent on the support of a digital team in the organization. De Sousa Jabbour [11] identified the existence of competent employees as one of the main prerequisites of digital readiness. Elhusseiny et al. [19] emphasized the need to address the lack of skilled employees as a cornerstone in the implementation of Industry 4.0, highlighting the skills and potential of employees as a basis for this implementation. To describe these two elements of the digital infrastructure, the term "digital fitness" is used as the third and last digital infrastructure pillar defined as the level of digital capability in a project in terms of the digital competence of the employees on an individual level and the digital qualifiedness of the involved project teams as a whole.

Digital Teams as an Enabling Element of Digital Fitness

Guinan et al. [41] suggested four levers of an innovative digital project team, including talent management, continuous learning, iterative goal setting, and diverse and targeted team composition. To support the achievement of these levers, effective practices were suggested, such as training and mentoring digital team members, training digital team members on agile methods and leadership behaviors, establishing digital hubs, aligning project objectives with business strategy, and creating cross-functional teams. Digital teams have to be able to use Artificial Intelligence and obtain competencies in data science, data privacy and security, and machine learning [42]. Such teams have to be collaborative and flexible during the design and implementation of digital solutions [41]. Dery et al. [43] suggest that innovation teams are effective in integrating digital technologies into the innovation process. Hence, team members need to equip themselves with digital skills, agility, and improvisation. Furthermore, innovation teams must be able to adapt to dynamic environments with rapid changes and digital advancements [44]. Hadjielias et al. [45] suggest a model that traces the functions of an innovation team across different stages of a digital innovation project and concludes that the ability of an innovation team to function in a digital environment depends on team-specific cognitions and digital project-specific cognitions. Team cognitions are dynamic phenomena [46], which refers, according to

MacMillan et al. [47], to the brain of the team and the way information is utilized through the construction of mental models [48].

Digitally Competent Employees as an Enabling Element of Digital Fitness

Vazirani [49] defined competence as the capability of a set of alternate behaviors organized around an underlying construct, requiring both intent and action. Competencies in the context of Industry 4.0 are abilities to use Industry 4.0 knowledge and to make things happen [50]. Competencies must include signs of intent, motives, social roles, traits, and knowledge [51]. The behavioral nature of competencies is manifest in its three main types defined by Vazirani [49]: cognitive competencies, emotional intelligence competencies, and social intelligence competencies. Cartwright et al. [52] referred to the PMI to define competencies in the context of Project Management in three dimensions: knowledge, performance, and personal characteristics. In comparison, the International Project Management Association [53] divides the competencies in Project Management into technical, contextual, and behavioral competencies. Pessl [54] categorized competencies into technical competencies, such as knowledge, understanding, and technical skills; methodological competencies, such as creativity, conflict-solving, and decision-making; social competencies, such as language skills, communication skills, and networking skills; and personal competencies, such as flexibility, working under pressure, and compliance. The introduction of CPS and IoT as part of the introduction of Industry 4.0 is creating room for the development and use of more effective and predictive Project Management tools to replace those that have not changed during the last 30 years since Industry 3.0 was introduced [55]. For example, the soft skills of a project manager in the context of Industry 4.0 are witnessing remarkable transformation, mainly related to the new approaches to interacting with project stakeholders [56]. Such soft skills include communication skills, authority, team management, management of unforeseen events, and negotiation skills. In terms of communication skills, Industry 4.0 enables a project manager to react in real time, share knowledge, and create integrated collaboration with stakeholders to speed up problem-solving and decision-making and enhance the management of critical organizational issues. Industry 4.0 also enables a project manager to assume a more authoritative leadership role as a result of the main role of Industry 4.0 in the process of industrialization change. A project manager will be enabled by digitalization to delocalize the work of project teams to improve the composition of these teams and enhance team management. Project managers will also be enabled by Industry 4.0 to have a consistent problem-solving capacity and undertake quick actions as a result of the integrated flow of data and communications, allowing high-speed, real-time decision-making in times when unexpected events unfold. Industry 4.0 will also transform traditional hierarchical structures into flat structures with greater communication freedom built on transparency, comprehensive knowledge, and responsibility that can lead to better negotiation of project terms with project members who will gradually become independent professional figures. The hard skills of a project manager are also witnessing noticeable transformation as they play an essential role in a project [56]. Such hard skills include technical experience with innovative technologies, innovative projects, predictive algorithms, and big data analysis. These hard skills in the context of Industry 4.0 will enable project managers to lead the components of the project with a detailed outlook rather than a generic approach. The skills of a project manager in relation to communication, interaction, work capacity, and basic project-related knowledge have to improve for better adaptation of the project manager into digitalized work environments and Industry 4.0 integration in project works [57]. The study indicates that the competencies needed for the project management role go beyond the generally defined ones. Accordingly, project managers must enhance their soft skills, hard skills, and basic knowledge about the project to achieve project management success. The following enablers were deduced to represent the enabling elements of digital fitness as a pillar of digital infrastructure, as shown in Table 3.

Table 3. Enabling elements of Digital Fitness as a pillar of digital infrastructure.

Enabler of Digital Fitness	Code	Description	Reference
Digital Teams	DF1	Digital Fitness Enabling Element 1	[41–43]
Digitally Competent Employees	DF2	Digital Fitness Enabling Element 2	[11,19,57]

2.2. Project Management Success Indicators

In the pursuit of Alias et al. [58] to identify the critical success factors of project management practice in the construction industry, project performance indicators were identified to measure the success of a construction project. These indicators include cost (compliance with the budget), time (compliance with the schedule), quality (compliance with quality requirements and specifications), and client satisfaction. In line with these findings, Adywiratama [59] identified seven criteria to measure the degree to which the project is described to have achieved its goals, including time, budget, scope, quality, value creation, stakeholder satisfaction, and risk. In Marques et al. [60], the previous findings were partially confirmed in the context of software development projects' success by reiterating that budget compliance, meeting schedule, meeting scope, and stakeholder satisfaction are the four main success criteria of such projects.

Time, cost, and quality are also identified as the main KPIs in project success by many other authors. However, Lester [61] states that other criteria can be equally or more important in other industries and contexts, such as legacy, sustainability, safety, and reliability. Such KPIs cannot be measured right at the end of the project but are rather determined in the long run.

Project success is not necessarily a prerequisite for project management success and likewise, the success of project management does not necessarily imply the success of a project although it does in most cases [62]. Therefore, project management success is dependent on success criteria such as time, scope, resources, cost, quality, and activities; but also on performance measurement models such as project management performance assessment, or organizational maturity management models such as project excellence. Sulistiyani et al. [63] explored factors that measure IT project success and came up with the conclusion that it can mostly be explained by technical variability, organizational benefits from the project, product/service quality, and stakeholder acceptance. Furthermore, Ahmed et al. [64] investigated the role of decision-making and big data analytics on project success by studying the relationship between these two factors with five project success dimensions identified in the project success measurement model developed by Shenhar et al. [65]. These dimensions are project efficiency, direct business and organizational success, project impact on the customer, project impact on the team, and how the project prepares for the future. Kanski et al. [8] shortlisted nine key components enabling the evolution of project success and indicating the level of this success. These key components include compliance with the budget, compliance with the schedule, ensuring functionality, customer satisfaction, project team members' satisfaction, ensuring benefits to the company, achieving the company's strategic objectives, work environment and knowledge sharing culture, and contractual penalties.

In conclusion, different success indicators have been identified in the body of literature to identify the success of a project and its management. However, some of these indicators are dependent on the type of project and its output. Accordingly, a list of the indicators that will be used to identify the success of a project in this research is created as summarized in Table 4, comprehensively covering all types of projects and approaches to project management. These success indicators will also be used as the indicators of project management success in the survey.

Table 4. Project Management Success Indicators.

Project Management Success Indicators	Code	Description	Reference
Compliance with the Budget	C1	Criterion 1	[58]
Compliance with the Schedule	C2	Criterion 2	[60]
Compliance with Quality Requirements and Specifications	C3	Criterion 3	[58]
Meeting the Scope of the Project	C4	Criterion 4	[60]
Stakeholder Satisfaction	C5	Criterion 5	[59]
Satisfaction of Project team members	C6	Criterion 6	[8]
Ensuring long-run organizational benefits	C7	Criterion 7	[63]
Achieving the strategic objectives of the Organization	C8	Criterion 8	[8]
Achieving legacy	C9	Criterion 9	[61]
Sustainability of solutions and success	C10	Criterion 10	[61]
Risk Minimization	C11	Criterion 11	[59]

2.3. Multi-Criteria Analysis

The Multiple Criteria Decision Making (MCDM) is a multi-criteria analysis approach that methodically uses benefit and non-benefit decision criteria to select an optimum alternative from a list of alternatives [66]. There are different MCDM tools, such as AHP, ELECTRE, and TOPSIS, which can be used to rank alternatives based on decision criteria in diverse decision problems in various fields and industries [67]. The majority of papers in the body of literature showed that MCDM tools can significantly improve decision-making in scenarios involving multiple conflicting decision criteria [67–69]. Kabir et al. [66] state that the hybrid method integrating more than one MCDM tool is the most frequently used approach in all fields and applications.

The Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) is an MCDM tool that has been validated for identifying the ideal solution among a list of alternatives. TOPSIS considers the proximity to the best option and the remoteness from the worst option while identifying the optimum alternative based on these two factors. TOPSIS has proven to be a reliable, effective, and robust MCDM tool due to its solid theoretical foundation and numerous successful applications in various domains [70]. Chen [70] introduced an extension of the traditional TOPSIS method in a fuzzy environment, known as the FTOPSIS methodology. In circumstances of high uncertainty in the decision-making process, the use of fuzzy logic grows more important to clear out this uncertainty and vagueness, and hence, FTOPSIS can be used to select one or more alternatives with reference to multiple criteria. FTOPSIS is particularly beneficial when the information known about the alternatives and their application in the field of study is either imprecise or ambiguous and vague. In such cases, the input of the experts into the TOPSIS decision matrix will provide a subjective judgment using linguistic variables based on a realistic representation of the effectiveness of alternatives in serving the goal of the study with reference to the identified criteria [71]. Several research papers have used TOPSIS in the ranking of alternatives related to digital technologies and applications in several fields. For example, Tanveer et al. [72] used FTOPSIS to select digital technologies in circular supply chains. Moreover, Satı [73] used entropy weight TOPSIS to compare the criteria affecting digital innovation performance and investigate its importance in SMEs. Furthermore, Forcina et al. [74] developed a TOPSIS-based decision support system to explore Industry 4.0 technologies to improve manufacturing enterprise safety management. With more relevance to the digital infrastructure addressed in this research, Tabatabaei [75] used TOPSIS to evaluate the impact of the variables of organizational culture on the success of knowledge management in organizations while addressing the challenges and opportunities presented in a digital transformation environment.

The FAHP and FTOPSIS methods are among the most influential MCDM tools in criteria and alternative assessments [76]. Alhassan et al. [77] used this hybrid FAHP-FTOPSIS approach to rank the practices of mercury risk reduction, and Abdullah et al. [78] used the same hybrid approach to rank the strategies and practices to overcome the barriers of sustainable manufacturing implementation. This approach was also used by Velmurugan et al. [79] to develop an optimal decision support model for a maintenance management system that prioritizes human error factors in a specific manufacturing industry. Moreover, Ekmekcioğlu et al. [80] used this approach to prioritize districts of Istanbul based on flood risk.

3. Methodology

The methodology of this study utilized an MCA approach to weigh and rank the enabling elements of digital infrastructure required for project management success. The methodology begins with the insights extracted from the comprehensive literature review conducted for this study, which identified the three key pillars of digital infrastructure required to achieve project management success. The Section 2 has also identified specific enabling elements of digital infrastructure within each pillar, as well as project management success indicators that serve as criteria in the MCA.

Data collection was conducted through three sequential surveys. While Survey 1 was designed based on the literature review findings, Surveys 2 and 3 were designed based on the outcomes of their preceding surveys. Therefore, the results of Survey 1 have contributed to the design of Surveys 2 and 3, while the results of Survey 2 have contributed to the design of Survey 3, necessitating a rigorous survey design process. The collected data from the three surveys were tabulated and utilized as input for the MCA, which was conducted in three steps: first, the AHP was used to shortlist the criteria based on the ranking results; second, the FAHP was applied to weigh these criteria and shortlist the enabling elements associated with the digital readiness pillar; and third, FTOPSIS was used to rank all enabling elements of digital infrastructure across the three pillars.

The methodology concludes with a scenario analysis, altering the weights of criteria in three scenarios to assess their impact on the final ranking of enabling elements. The scenario analysis assessed the sensitivity of the results of the study and enhanced the robustness of the findings. The findings of the MCA and the scenario analysis have contributed to understanding the role of digital infrastructure in project management success and highlighting the most effective enabling elements in achieving this success. A research methodology diagram is shown in Figure 1, whereby the steps of the methodology are mapped with the research questions and research objectives.

3.1. Survey Design and Distribution

The results of this article were principally based on the MCA, in which the enabling elements of digital infrastructure were considered as the alternatives of the analysis, while project management success indicators were used as the criteria. To collect the required comparison data for both the criteria and the alternatives, three surveys were designed and distributed.

As a first step, it was necessary to calculate the weights of the criteria of the analysis before starting to compare the alternatives. Nevertheless, the number of the identified criteria was 11, which necessitated conducting Survey 1 to collect the required data, which was first used to reduce the number of the criteria using AHP by eliminating the least weighted criteria at a specific weight cut-off limit specified by the significant weight difference between the criteria. Survey 1 also aimed to provide the necessary data to calculate the criteria weights in the MCA analysis and, hence, measured the relative importance of project management success indicators in comparison to each other. The data collected from Survey 1 was used again, after eliminating the comparison numbers of the excluded criteria, as an input for a FAHP analysis to compare the shortlisted criteria and calculate their associated weights to be used in the next step of the MCA. Accordingly, Survey 1 was designed on the basis of a table incorporating 55 entries representing 55 pairwise comparisons between each one of the 11 criteria with each other. The shortlisted criteria were used as the final criteria in Survey 3.

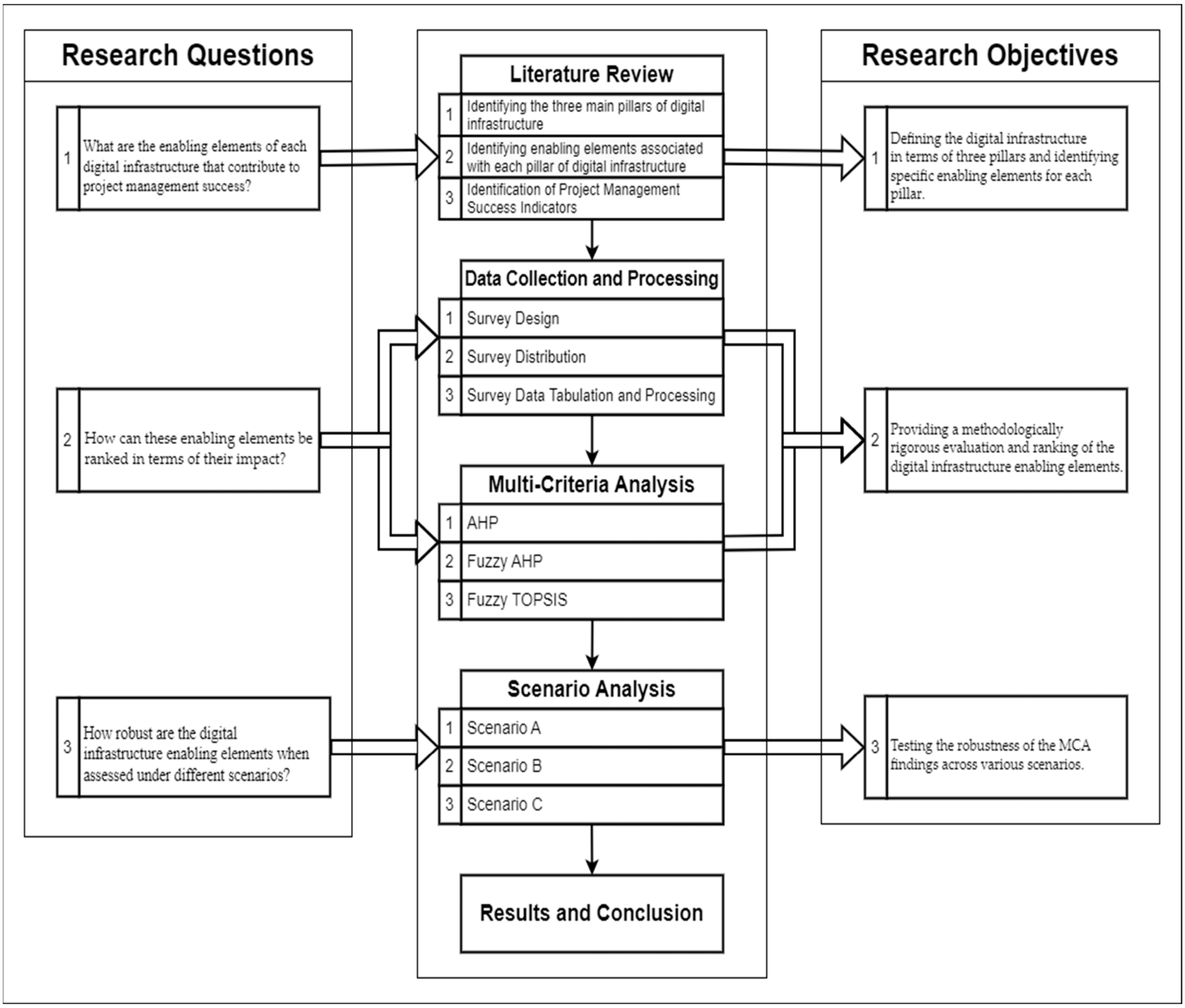

Figure 1. Research Methodology Diagram.

The second step was to shortlist the digital infrastructure enabling elements associated with digital readiness since these elements identified in the literature review have noticeably outnumbered the elements identified in association with the two other pillars (digital tools and digital fitness). Therefore, Survey 2 aimed to measure the relative importance of the seven enabling elements associated with digital readiness by comparing these elements with each other through 21 pairwise comparisons. The comparison numbers from Survey 2 provided the required data for the FAHP analysis that will eliminate the least weighted enabling elements at a specified weight cut-off limit. The shortlisted enabling elements associated with digital readiness were used alongside the four other digital infrastructure enabling elements (associated with digital tools and digital fitness) in designing the questions of Survey 3.

Survey 3 aimed to collect experts' responses on the importance of each digital infrastructure enabling element in achieving project management success in terms of each of the project management success indicators (criteria) shortlisted in Survey 1. Survey 3 was designed on the basis of a table incorporating 56 entries representing 56 questions. Each set ofseven questions was assigned to one of the final eight enabling elements, to measure the importance of this element in achieving project management success in terms of each one of the seven final criteria. Figure 2 presents a diagram illustrating the survey design process, detailing the inputs provided for each of the three surveys.

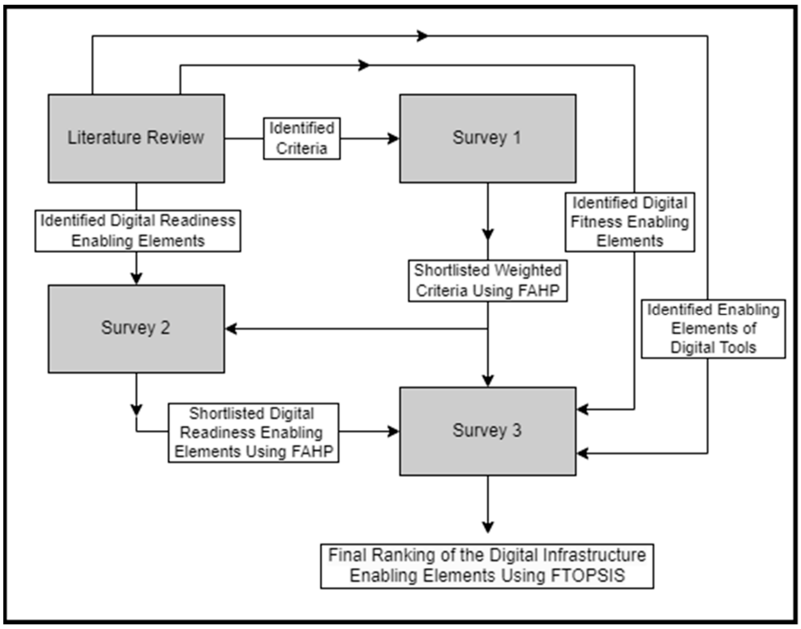

Figure 2. The survey design process.

Survey 1 was distributed to 32 respondents who identified as project management experts with more than 15 years of experience as project managers. Surveys 2 and 3 were distributed to 99 respondents who identified as experienced individuals in both project management and Industry 4.0. The combination of expertise in both fields was important in surveys 2 and 3 to establish a link between digital infrastructure and project management. Therefore, respondents of surveys 2 and 3 had to align with the criteria of more than 5 years of experience in both fields. To be able to filter responses later based on the compliance of the respondent with the aforementioned criteria, each one of the three surveys included an introduction section with demographic questions about the respondent's project management knowledge and experience, as well as knowledge and experience in digitalization and Industry 4.0 technologies.

3.2. Multi-Criteria Analysis

This article has followed several steps to conduct the MCA. A hybrid approach of AHP, FAHP, and FTOPSIS was used in this analysis to conclude the final weights and ranking of enabling elements of digital infrastructure pillars leading to project management success. AHP was used initially to shortlist the criteria, and then FAHP was used to calculate the weights for the shortlisted criteria, and FTOPSIS was finally used to rank the alternatives. The MCA was conducted as per the following steps:

3.2.1. Step 1

AHP [81] was used to weigh and rank the 11 project management success indicators that act as the criteria in the analysis. The use of AHP was to weigh and rank the 11 criteria to reduce their number from 11 to 7 based on a weight cut-off limit of 0.05. The AHP pairwise comparison for the criteria is done as per Equation (1) using the pairwise comparison numbers indicated in Table 5.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & 1 & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} \quad (1)$$

Table 5. Linguistic terms and their FAHP numbers.

Linguistic Judgement for AHP/FAHP Pairwise Comparisons	Comparison Number	Triangular Fuzzy Number	Triangular Fuzzy Reciprocals
Equally Important	1	(1,1,1)	(1,1,1)
Intermediate Value of Relative Importance Between 1 and 3	2	(1,2,3)	(1/3,1/2,1)
Marginally More Important	3	(2,3,4)	(1/4,1/3,1/2)
Intermediate Value of Relative Importance Between 3 and 5	4	(3,4,5)	(1/5,1/4,1/3)
More Important	5	(4,5,6)	(1/6,1/5,1/4)
Intermediate Value of Relative Importance Between 5 and 7	6	(5,6,7)	(1/7,1/6,1/5)
Significantly More Important	7	(6,7,8)	(1/8,1/7,1/6)
Intermediate Value of Relative Importance Between 7 and 9	8	(7,8,9)	(1/9,1/8,1/7)
Extremely More Important	9	(9,9,9)	(1/9,1/9,1/9)

3.2.2. Step 2

FAHP [82] was used to weigh the seven shortlisted criteria. This step starts with a FAHP pairwise comparison matrix expressed in Equation (2). The project management success indicators identified are compared for their relative importance through the input of experts based on the triangular fuzzy numbers [83] associated with the FAHP linguistic pairwise comparison judgments, as shown in Table 5. The fuzzy pairwise comparison matrix for the criteria is indicated in Equation (2) as follows:

$$A = \begin{bmatrix} (1,1,1) & \widetilde{a}_{12} & \cdots & \widetilde{a}_{1n} \\ \widetilde{a}_{21} & (1,1,1) & \cdots & \widetilde{a}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & \cdots & (1,1,1) \end{bmatrix} = \begin{bmatrix} (1,1,1) & \widetilde{a}_{12} & \cdots & \widetilde{a}_{1n} \\ (1,1,1)/\widetilde{a}_{12} & (1,1,1) & \cdots & \widetilde{a}_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ (1,1,1)/\widetilde{a}_{1n} & (1,1,1)/\widetilde{a}_{2n} & \cdots & (1,1,1) \end{bmatrix} \quad (2)$$

where $\widetilde{a}_{ij} \times \widetilde{a}_{ji} \approx 1, \widetilde{a}ij = (l_{ij}, m_{ij}, u_{ij}), and\ \widetilde{a}_{ji}^{-1} = \left(\frac{1}{uij}, \frac{1}{mij}, \frac{1}{lij}\right)$

Then the fuzzy synthetic extent with reference to criterion i (S_i) is calculated using Equation (3):

$$Si = \sum_{j=1}^{n} \widetilde{a}_{ij} \left[\sum_{i=1}^{n} \sum_{j=1}^{n} \widetilde{a}_{ij}\right]^{-1} \quad (3)$$

where $\sum_{j=1}^{n} \widetilde{a}_{ji} = \left(\sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j\right), \sum_i^n \times \sum_j^n \widetilde{a}_{ij} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$

And $\left[\sum_{i=1}^{n} \sum_{j=1}^{n} \widetilde{a}_{ij}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$

3.2.3. Step 3

FTOPSIS [70] is then used to weigh and rank the enabling elements of the digital infrastructure pillars acting as alternatives to the MCA. The fuzzy decision matrix for the alternatives is shown in Equation (4), where $\widetilde{D} = \left[\widetilde{X}_{ij}\right]$.

$$\widetilde{D} = \begin{matrix} & C_1 & C_j & C_n \\ A_1 \\ A_i \\ A_m \end{matrix} \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix} \quad (4)$$

The FTOPSIS decision matrix ($\widetilde{D}$) is filled with triangular fuzzy numbers [84] based on the linguistic judgment, as shown in Table 6. The linguistic terms for alternative ratings in this research have been adjusted to suit the context of the topic. The fuzzy decision matrix ($\widetilde{D}$) has to be normalized as per Equation (5) into a normalized decision matrix $\widetilde{R}$. The normalized value for the beneficial criteria is calculated using Equation (6), and the non-beneficial criteria is calculated using Equation (7).

$$\widetilde{R} = \left[\widetilde{r}_{ij}\right]_{m\times n},\ i = 1,2,\ \ldots, m \ and\ j = 1,2,\ldots,m \quad (5)$$

$$\widetilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right),\ u_j^+ = max_i\ (beneficial\ criteria) \quad (6)$$

$$\widetilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right),\ l_j^- = min_i\ (non - beneficial\ criteria) \quad (7)$$

Table 6. Linguistic terms and their triangular FTOPSIS numbers.

Linguistics Terms for Alternatives Ratings	Triangular Fuzzy Number
Little or Not Important	(1,1,3)
Somewhat Important	(1,2,4)
Slightly Important	(1,3,5)
Important	(2,4,6)
Moderately Important	(3,5,7)
Fairly Important	(4,6,8)
Strongly Important	(5,7,9)
Very Strongly Important	(6,8,9)
Extremely Important	(7,9,9)

The next step is to weigh the normalized decision matrix $\widetilde{R}$ by multiplying it by the weights of the criteria to obtain a normalized decision matrix $\widetilde{V}$ as shown in Equation (8).

$$\widetilde{V} = \left[\widetilde{V}_{ij}\right]_{m\times n} = \widetilde{r}_{ij} \times w_j \quad (8)$$

The fuzzy ideal positive solution (A^*) and the fuzzy ideal negative solution (A^-) are calculated using Equation (9) and Equation (10), respectively, for the distance of each alternative from each one of these solutions to be calculated. The distance of an alternative from the fuzzy ideal positive solution (A^*) is denoted as d_i^*; it is calculated using Equation (11), while the distance from the fuzzy negative ideal solution is denoted as d_i^-; it is calculated using Equation (12).

$$A^* = \left\{\widetilde{v}_1^*, \widetilde{v}_j^*, \ldots, \widetilde{v}_m^*\right\},\ where\ \widetilde{v}_j^* = max_i\left\{\widetilde{v}_{ij3}\right\} \quad (9)$$

$$A^- = \left\{\widetilde{v}_1^-, \widetilde{v}_j^-, \ldots, \widetilde{v}_m^-\right\},\ where\ \widetilde{v}_j^- = max_i\left\{\widetilde{v}_{ij3}\right\} \quad (10)$$

$$d_i^* = \sum_{j=1}^{n} d\left(\widetilde{v}_{ij}, \widetilde{v}_j^*\right),\ i = 1,2,\ldots,m \ and\ j = 1,2,\ldots,n \quad (11)$$

$$d_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right),\ i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n \tag{12}$$

The distance between each alternative and the ideal solution, whether the positive or the negative solution, is calculated using Equation (13).

$$d\left(\tilde{a}_1, \tilde{a}_2\right) = \sqrt{\frac{1}{3}\left[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2\right]} \tag{13}$$

The distances from the fuzzy ideal negative solution (d_i^-) and the fuzzy ideal positive solution (d_i^*) are calculated to finally calculate CC_i as shown in Equation (14). CC_i is described as the closeness coefficient and will be used to indicate the closeness of the alternative to the FIPS and its distance away from FINS. Therefore, the higher the value of CC_i, the more priority is given to the alternative.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-},\ i = 1, 2, \ldots, m \tag{14}$$

4. Results

4.1. Survey Results

Out of the 32 experts to whom Survey 1 was sent, 15 responded. 1 response out of the 15 was then excluded as the respondent did not meet the respondent experience criteria. For Survey 2, 11 responses were received from respondents who have met the experience criteria out of 19 total responses. On the other hand, 12 responses were recorded from respondents who met the respondent criteria for Survey 3 out of 23 total responses received. Table 7 shows the number of respondents for each survey, the response rate, and the compliance of respondents with the respondent criteria calculated by dividing the number of complying responses by the number of responses received. Moreover, Figure 3 shows the number of responses based on the sector, highlighting a fair distribution of respondents in all sectors.

Table 7. Number of responses on the three surveys, response rate, and response compliance rate.

Title 1	Number of Responses	Response Rate	Response Compliance Rate
Survey 1	14	46.875%	93.33%
Survey 2	11	19.19%	57.89%
Survey 3	12	23.23%	52.17%

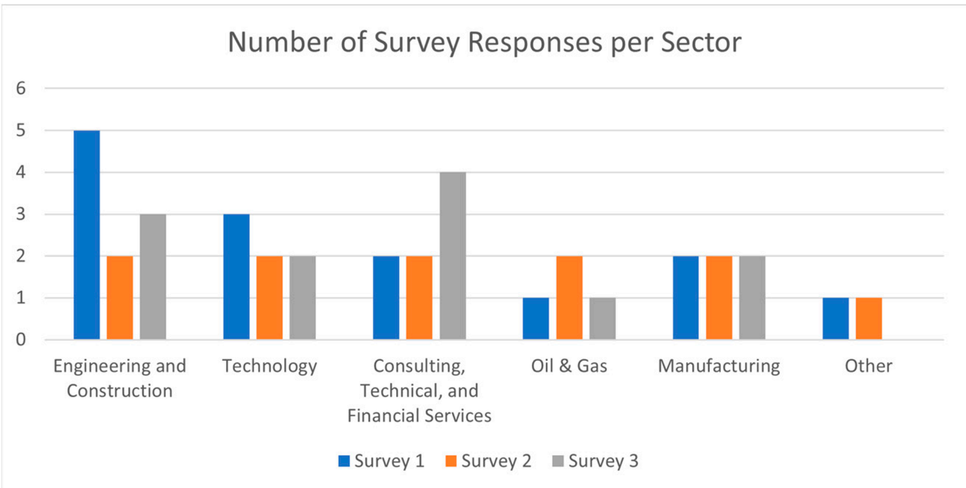

Figure 3. Number of responses per sector.

4.2. Results of the Multi-Criteria Analysis

The AHP methodology was first applied to the criteria as per step 1 in the methodology, to reduce the number of criteria from 11 to 7 based on a weight cut-off limit of 0.05. Table 8 shows the AHP pairwise comparison between the decision criteria as well as the final criteria weights and ranks. The four criteria with the minimum weights were excluded from the analysis. The consistency ratio of the AHP analysis was 0.05423, and hence, the analysis was considered consistent. After the exclusion of the four least weighted criteria, the criteria code numbering was redone according to Table 9.

Table 8. Criteria Weights and Ranks based on AHP pairwise comparison of criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Weight	Rank	Included/Excluded
C1	1	1/3	1	1/3	3	5	3	1/3	5	3	5	0.1029	4	Included
C2	3	1	3	1	7	7	3	1	7	5	7	0.1995	1	Included
C3	1	1/3	1	1/3	5	3	1	1/3	3	3	3	0.0829	5	Included
C4	3	1	3	1	7	7	3	1	5	5	5	0.1907	2	Included
C5	1/3	1/7	1/5	1/7	1	1	1/3	1/5	3	1/3	3	0.0341	8	Excluded
C6	1/5	1/7	1/3	1/7	1	1	1/3	1/5	1	1/3	3	0.0293	9	Excluded
C7	1/3	1/3	1	1/3	3	3	1	1/3	5	1	5	0.0743	6	Included
C8	3	1	3	1	5	5	3	1	5	5	5	0.1806	3	Included
C9	1/5	1/7	1/3	1/5	1/3	1	1/5	1/5	1	1/3	3	0.0279	10	Excluded
C10	1/3	1/5	1/3	1/5	3	3	1	1/5	3	1	5	0.0576	7	Included
C11	1/5	1/7	1/3	1/5	1/3	1/3	1/5	1/5	1/3	1/5	1	0.0201	11	Excluded
Sum	12.6	4.77	13.5	4.89	35.67	36.3	16.07	5	38.3	24.2	45	1	-	-

Table 9. The MCA Criteria after excluding low-weight criteria.

New Criteria Code	Project Management Success Indicator/Criteria
C1	Compliance with the budget
C2	Compliance with the schedule
C3	Compliance with quality requirements and specifications
C4	Meeting the scope of the project
C5	Ensuring long-run organizational benefits
C6	Achieving the strategic objectives of the organization
C7	Sustainability of solutions and success

The FAHP was then applied as per step 2 of the methodology to the seven criteria to deduce their weights. These weights calculated using FAHP will be used in their fuzzy form in the FTOPSIS (step 3 of the methodology) to rank the enabling elements of the pillars of digital infrastructure. Table 10 shows the FAHP pairwise comparison of the 7 MCA criteria after eliminating the four least-weighted criteria. The fuzzy, defuzzified, and normalized weights of the criteria calculated using FAHP are indicated in Table 11.

Table 10. FAHP pairwise comparison of criteria.

	C1	C2	C3	C4	C5	C6	C7
C1	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(2,3,4)
C2	(2,3,4)	(1,1,1)	(2,3,4)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)
C3	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(1,1,1)
C4	(1,1,1)	(1,1,1)	(2,3,4)	(1,1,1)	(2,3,4)	(1,1,1)	(2,3,4)
C5	(1,1,1)	(1/4,1/3,1/2)	1	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(2,3,4)

Table 10. *Cont.*

	C1	C2	C3	C4	C5	C6	C7
C6	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(2,3,4)
C7	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1,1,1)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)

Table 11. Fuzzy criteria weights.

Criteria	Fuzzy Geometric Mean		Reciprocal of Fuzzy Geometric Mean Summation	Fuzzy Weights	Defuzzified Weights	Normalized Weights
C1	(0.906,1,1.104)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.098,0.125,0.164)	0.129	0.124921524
C2	(1.811,2.358,2.852)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.196,0.296,0.423)	0.305	0.295158856
C3	(0.673,0.731,0.82)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.073,0.092,0.122)	0.095	0.092314654
C4	(1.346,1.601,1.811)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.146,0.201,0.269)	0.205	0.198476186
C5	(0.743,0.855,1)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.08,0.107,0.148)	0.112	0.108383913
C6	(0.906,1,1.104)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.098,0.125,0.164)	0.129	0.124921524
C7	(0.351,0.424,0.552)	×	$\left(\frac{1}{9.244}, \frac{1}{7.969}, \frac{1}{6.735}\right)$	(0.038,0.053,0.082)	0.058	0.055823344

This step in the MCA aimed to use FAHP (step 2 of methodology) to reduce the number of enabling elements of digital readiness from 7 to 4 enabling elements. The main reason why digital readiness enabling elements were shortlisted is the fact that three of them have had significantly lower weights than other elements. Therefore, these three criteria were ruled out at a cut-off limit of 10%, and only the enabling elements with weights higher than 10% were kept in the analysis. Table 12 shows the FAHP pairwise comparison between the enabling elements of digital readiness, while Table 13 shows the normalized weights of these enabling elements.

Table 12. FAHP pairwise comparison of Digital Readiness enabling elements.

	DR1	DR2	DR3	DR4	DR5	DR6	DR7
DR1	(1,1,1)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(2,3,4)	(2,3,4)	(4,5,6)	(4,5,6)
DR2	(2,3,4)	(1,1,1)	(2,3,4)	(2,3,4)	(2,3,4)	(6,7,8)	(6,7,8)
DR3	(2,3,4)	(1/4,1/3,1/2)	(1,1,1)	(2,3,4)	(2,3,4)	(6,7,8)	(6,7,8)
DR4	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)	(2,3,4)	(4,5,6)	(4,5,6)
DR5	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)	(2,3,4)	(4,5,6)
DR6	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1,1,1)	(2,3,4)
DR7	(1/6,1/5,1/4)	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1,1,1)

Table 13. FAHP Digital Readiness enabling elements weights.

DR Enabling Element	Fuzzy Geometric Mean		Reciprocal of Fuzzy Geometric Mean Summation	Fuzzy Weights	Defuzzified Weights	Normalized Weights	Rank	Included/Excluded
DR1	(1.22,1.58,2.03)	×	$\left(\frac{1}{12.32}, \frac{1}{9.788}, \frac{1}{7.566}\right)$	(0.099,0.162,0.269)	0.1765	0.1633	3	Included
DR2	(2.48,3.27,4)	×	$\left(\frac{1}{12.32}, \frac{1}{9.788}, \frac{1}{7.566}\right)$	(0.201,0.334,0.529)	0.3546	0.328	1	Included

Table 13. *Cont.*

DR Enabling Element	Fuzzy Geometric Mean		Reciprocal of Fuzzy Geometric Mean Summation	Fuzzy Weights	Defuzzified Weights	Normalized Weights	Rank	Included/Excluded
DR3	(1.84,2.39,2.97)	×	$\left(\frac{1}{12.32},\frac{1}{9.788},\frac{1}{7.566}\right)$	(0.15,0.244,0.393)	0.2621	0.2424	2	Included
DR4	(0.91,1.16,1.51)	×	$\left(\frac{1}{12.32},\frac{1}{9.788},\frac{1}{7.566}\right)$	(0.074,0.118,0.2)	0.1305	0.1207	4	Included
DR5	(0.61,0.79,1.06)	×	$\left(\frac{1}{12.32},\frac{1}{9.788},\frac{1}{7.566}\right)$	(0.049,0.08,0.14)	0.0899	0.0832	5	Excluded
DR6	(0.3,0.36,0.45)	×	$\left(\frac{1}{12.32},\frac{1}{9.788},\frac{1}{7.566}\right)$	(0.024,0.037,0.059)	0.0401	0.0371	6	Excluded
DR7	(0.21,0.25,0.3)	×	$\left(\frac{1}{12.32},\frac{1}{9.788},\frac{1}{7.566}\right)$	(0.017,0.025,0.04)	0.0273	0.0252	7	Excluded

The third and last step in the MCA was to weigh and rank all enabling elements of digital infrastructure regardless of the associated pillar of digital infrastructure. This step was done using FTOPSIS, as explained in step 3 of the methodology, in which a triangular fuzzy number was assigned to each enabling element based on the linguistic term for the alternative rating as per Table 6. The fuzzy matrix was developed for each one of the 12 experts participating in Survey 3. A sample of this fuzzy matrix is provided in Table 14 based on the input of the first expert. The input of all 12 experts was normalized in a normalized fuzzy decision matrix, as shown in Table 15, and then weighted into a fuzzy weighted normalized decision matrix, as shown in Table 16, which also shows the Fuzzy Ideal Positive Solution (FIPS) denoted as A^* and calculated using Equation (9), as well as the Fuzzy Ideal Negative Solution (FINS) denoted as A^-, and calculated using Equation (10).

Table 14. Fuzzy decision matrix for alternatives with respect to criteria (Expert 1 input).

	C1	C2	C3	C4	C5	C6	C7
DR1	(2,4,6)	(2,4,6)	(4,6,8)	(4,6,8)	(4,6,8)	(3,5,7)	(5,7,9)
DR2	(2,4,6)	(4,6,8)	(1,3,5)	(1,3,5)	(4,6,8)	(5,7,9)	(4,6,8)
DR3	(7,9,9)	(4,6,8)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)	(4,6,8)
DR4	(4,6,8)	(3,5,7)	(4,6,8)	(5,7,9)	(5,7,9)	(4,6,8)	(4,6,8)
DT1	(3,5,7)	(7,9,9)	(5,7,9)	(7,9,9)	(3,5,7)	(3,5,7)	(6,8,9)
DT2	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)	(4,6,8)	(3,5,7)	(3,5,7)
DF1	(7,9,9)	(7,9,9)	(6,8,9)	(4,6,8)	(4,6,8)	(7,9,9)	(6,8,9)
DF2	(3,5,7)	(6,8,9)	(6,8,9)	(6,8,9)	(7,9,9)	(4,6,8)	(4,6,8)

Table 15. Fuzzy normalized decision matrix.

	C1	C2	C3	C4	C5	C6	C7
DR1	(0.11,0.55,1)	(0.11,0.58,1)	(0.11,0.54,1)	(0.11,0.58,1)	(0.11,0.5,1)	(0.11,0.45,1)	(0.11,0.64,1)
DR2	(0.11,0.48,1)	(0.11,0.55,1)	(0.11,0.51,1)	(0.11,0.56,1)	(0.11,0.56,1)	(0.11,0.56,1)	(0.11,0.56,1)
DR3	(0.11,0.67,1)	(0.22,0.69,1)	(0.11,0.6,1)	(0.11,0.62,1)	(0.11,0.66,1)	(0.33,0.73,1)	(0.22,0.65,1)
DR4	(0.11,0.56,1)	(0.11,0.56,1)	(0.11,0.57,1)	(0.11,0.57,1)	(0.11,0.6,1)	(0.11,0.5,1)	(0.11,0.58,1)
DT1	(0.33,0.77,1)	(0.33,0.77,1)	(0.33,0.77,1)	(0.44,0.85,1)	(0.33,0.68,1)	(0.33,0.67,1)	(0.33,0.82,1)
DT2	(0.33,0.81,1)	(0.33,0.81,1)	(0.44,0.85,1)	(0.33,0.79,1)	(0.33,0.75,1)	(0.33,0.8,1)	(0.33,0.84,1)
DF1	(0.11,0.71,1)	(0.22,0.71,1)	(0.11,0.64,1)	(0.11,0.66,1)	(0.22,0.7,1)	(0.11,0.7,1)	(0.11,0.66,1)
DF2	(0.33,0.69,1)	(0.33,0.81,1)	(0.33,0.66,1)	(0.33,0.88,1)	(0.44,0.83,1)	(0.33,0.8,1)	(0.33,0.81,1)

Table 16. Fuzzy weighted normalized decision matrix, FIPS, and FINS.

	C1	C2	C3	C4	C5	C6	C7
DR1	(0.01,0.07,0.16)	(0.02,0.17,0.42)	(0.01,0.05,0.12)	(0.02,0.12,0.27)	(0.01,0.05,0.15)	(0.01,0.06,0.16)	(0.004,0.03,0.08)
DR2	(0.01,0.06,0.16)	(0.02,0.16,0.42)	(0.01,0.05,0.12)	(0.02,0.11,0.27)	(0.01,0.06,0.15)	(0.01,0.07,0.16)	(0.004,0.03,0.08)
DR3	(0.01,0.08,0.16)	(0.04,0.2,0.42)	(0.01,0.06,0.12)	(0.02,0.12,0.27)	(0.01,0.07,0.15)	(0.03,0.09,0.16)	(0.01,0.03,0.08)
DR4	(0.01,0.07,0.16)	(0.02,0.17,0.42)	(0.01,0.05,0.12)	(0.02,0.12,0.27)	(0.01,0.06,0.15)	(0.01,0.06,0.16)	(0.004,0.03,0.08)
DT1	(0.03,0.1,0.16)	(0.07,0.23,0.42)	(0.02,0.07,0.12)	(0.06,0.17,0.27)	(0.03,0.07,0.15)	(0.03,0.08,0.16)	(0.01,0.04,0.08)
DT2	(0.03,0.1,0.16)	(0.07,0.24,0.42)	(0.03,0.08,0.12)	(0.05,0.16,0.27)	(0.03,0.08,0.15)	(0.03,0.1,0.16)	(0.01,0.05,0.08)
DF1	(0.01,0.09,0.16)	(0.04,0.21,0.42)	(0.01,0.06,0.12)	(0.02,0.13,0.27)	(0.02,0.08,0.15)	(0.01,0.09,0.16)	(0.004,0.04,0.08)
DF2	(0.03,0.09,0.16)	(0.07,0.24,0.42)	(0.02,0.06,0.12)	(0.05,0.18,0.27)	(0.04,0.09,0.15)	(0.03,0.1,0.16)	(0.01,0.04,0.08)
FIPS	(0.033,0.1,0.16)	(0.07,0.24,0.42)	(0.03,0.08,0.12)	(0.07,0.18,0.27)	(0.04,0.09,0.15)	(0.033,0.1,0.16)	(0.01,0.05,0.08)
FINS	(0.01,0.06,0.16)	(0.02,0.16,0.42)	(0.01,0.05,0.12)	(0.02,0.11,0.27)	(0.01,0.05,0.15)	(0.01,0.06,0.16)	(0.004,0.03,0.08)

Using Equations (11) and (12), d_i^* and d_i^- were calculated respectively, and CC_i was calculated accordingly using Equation (14). Table 17 shows the CC_i value for each enabling element and its associated rank. DT2 (Industry 4.0 enabling technologies) ranked first as the most effective enabling element for the digital infrastructure supporting project management success, followed by DF2, DT1, DR3, DF1, DR4, DR1, and DR2, respectively. The average CC_i value was calculated for each digital pillar in Table 18. The digital pillars were ranked accordingly, showing that Digital Tools ranks first, then Digital Fitness, and lastly Digital Readiness. Moreover, the relative weights were calculated based on the CCi for each enabling element, and the digital pillars were ranked accordingly. Digital Tools ranked first, followed by Digital Fitness, and lastly Digital Readiness, which presented the same ranking obtained as a result of the average CC_i.

Table 17. Distance of enabling elements (alternatives) from FIPS (d^*) and FINS (d^-), CC_i, and ranks.

Enabling Element	d^*	d^-	CC_i	Rank
DR1	0.197689	0.017203	0.080053	7
DR2	0.202653	0.011491	0.05366	8
DR3	0.13244	0.088836	0.40147	5
DR4	0.193519	0.02288	0.105732	6
DT1	0.041899	0.174437	0.806326	3
DT2	0.02153	0.190788	0.898595	1
DF1	0.126904	0.100371	0.441627	4
DF2	0.031799	0.187003	0.854668	2

Table 18. Average CC_i for enabling elements based on the associated digital pillar, and its rank.

Alternative	Enabling Element	Normalized Weight Based on CC_i	Average CC_i	Digital Pillar Rank Based on Average CC_i	Digital Pillar Relative Weight	Digital Pillar Rank Based on Digital Pillar Weight
DR1	Cybersecurity Systems	0.02198	0.160229	3	0.175973	3
DR2	Realtime Data Access and Management	0.014733				
DR3	Technological Infrastructure	0.110229				
DR4	Large Internet Capacity	0.02903				

Table 18. *Cont.*

Alternative	Enabling Element	Normalized Weight Based on CC_i	Average CC_i	Digital Pillar Rank Based on Average CC_i	Digital Pillar Relative Weight	Digital Pillar Rank Based on Digital Pillar Weight
DT1	Digital Transformation	0.221388	0.85246	1	0.468111	1
DT2	Industry 4.0 Enabling Technologies	0.246722				
DF1	Digital Teams	0.121255	0.648147	2	0.355917	2
DF2	Digitally Competent Employees	0.234661				

4.3. Scenario Analysis

In this analysis, the weights of the criteria were recalculated based on three scenarios denoted as Scenario A, B, and C. In Scenario A, it was assumed that all criteria had the same weights, while it was assumed in scenario B that "Compliance with the schedule" (C2) is not an important project management success indicator and was hence excluded as a criterion. Scenario C was similar to scenario B but it was "Compliance with the budget" (C1) that was excluded as a criterion from the analysis. The results of the scenario analysis indicated a change in the rank of enabling elements, as shown in Table 19 and Figure 4. DT2 (Industry 4.0 Enabling Technologies) remained the most effective enabling element of digital infrastructure in scenario A as it was in the original scenario. On the other hand, DF2 (Digitally Competent Employees) has ranked first in scenario B and scenario C. It was also noteworthy that the average CC_i for digital pillars has not changed significantly in the different proposed scenarios. This indicates that despite the different weights of the criteria, the digital infrastructure enabling elements associated with all digital pillars have had consistent, variating effects on project management success with respect to all criteria. Therefore, the ranking of enabling elements has had minor changes from one scenario to another.

Table 19. Ranking of Digital Infrastructure enabling elementsin Different Scenarios.

DI Enabling Element	Original Scenario			Scenario A			Scenario B			Scenario C		
	CC_i	Rank	Avg CC_i	CC_i	Rank	Avg CC_i	CC_i	Rank	Avg CC_i	CC_i	Rank	Avg CC_i
DR1	0.08	7	0.1602	0.078	7	0.155	0.063	7	0.1098	0.1212	6	0.1603
DR2	0.054	8		0.056	8		0.035	8		0.0029	8	
DR3	0.401	5		0.376	5		0.278	5		0.4545	5	
DR4	0.106	6		0.11	6		0.064	6		0.0625	7	
DT1	0.806	3	0.8525	0.799	3	0.852	0.868	2	0.8164	0.8417	3	0.8928
DT2	0.899	1		0.903	1		0.764	3		0.9439	2	
DF1	0.442	4	0.6481	0.385	4	0.611	0.373	4	0.6499	0.5585	4	0.7618
DF2	0.855	2		0.837	2		0.927	1		0.9651	1	

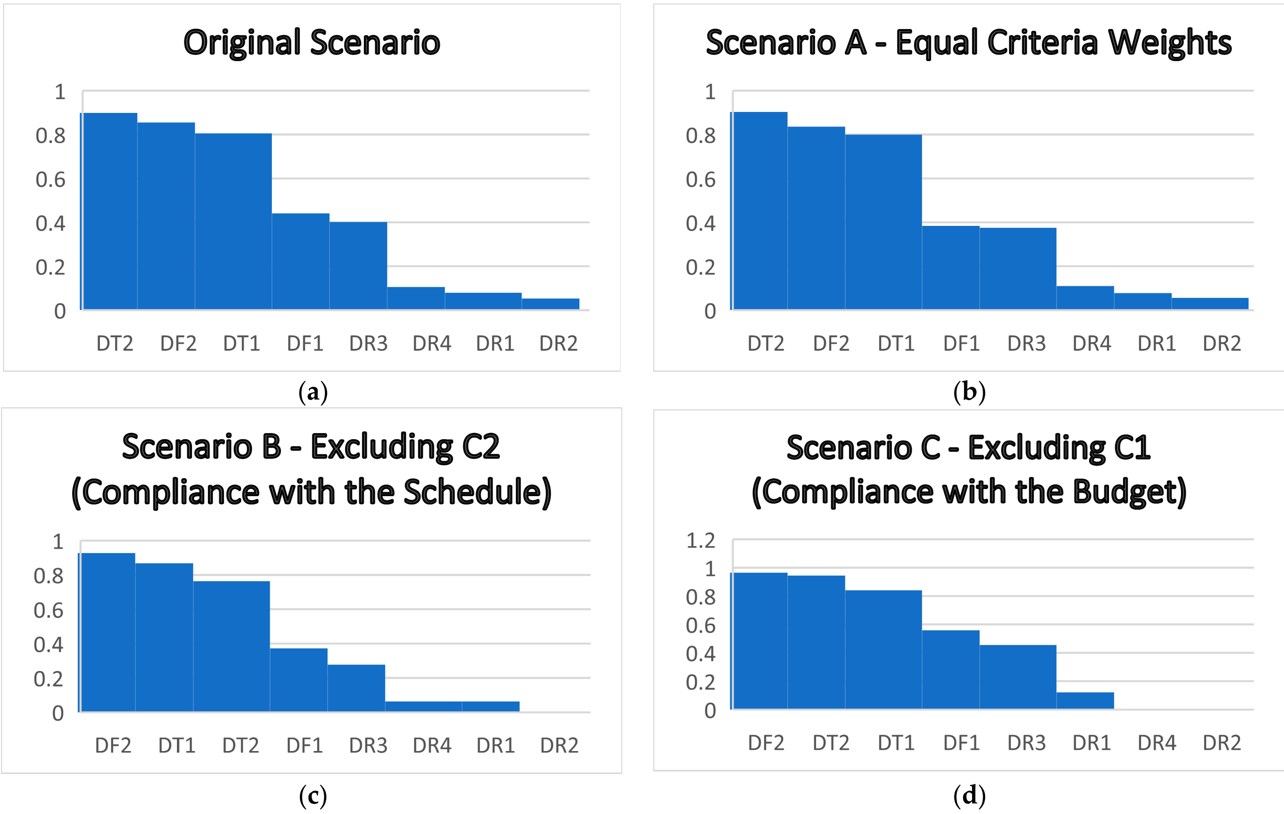

Figure 4. The scenario analysis for the eight enabling elements of digital infrastructure based on four scenarios (**a**) Original scenario; (**b**) Scenario A of equal criteria weights; (**c**) Scenario B whereby C1 (Compliance with the budget) is excluded; (**d**) Scenario C whereby C2 (Compliance with the schedule) is excluded.

5. Discussion

The findings of this study provide a comprehensive theoretical and practical understanding of the role of digital infrastructure, enabling elements in achieving project management success. The utilization of the hybrid MCA approach has provided conclusions on how different enabling elements associated with the three pillars of digital infrastructure contribute to project management success. This section reflects on the results, examines the implications of the rankings, and considers the broader context of these findings in the existing literature.

The survey distribution process involved respondents with extensive experience in project management and Industry 4.0. Therefore, datasets have been collected for use as the required input that laid the basis for the MCA. Survey 1 focused on gathering insights from project management experts, while Surveys 2 and 3 targeted respondents with experience in both project management and Industry 4.0. The dual expertise of respondents was crucial for linking digital infrastructure with project management success, reinforcing the validity and credibility of the results.

The use of AHP to reduce the number of criteria from 11 to 7 based on a weight cut-off limit was a key methodological decision that streamlined the analysis. This step effectively removed less influential criteria, maintaining analytical consistency with an acceptable consistency ratio (0.05423). The subsequent FAHP analysis further refined the criteria by calculating their normalized weights, which were then used in the FTOPSIS analysis to rank the enabling elements. This multi-step hybrid approach allowed for a detailed understanding of the relative importance of various elements with reference to multiple identified criteria.

The MCA has resulted in the identification of Industry 4.0 Enabling Technologies (DT2) as the most significant enabling element across the digital infrastructure pillars. This finding aligns with the emphasis of the literature on the critical role of advanced digital technologies, such as artificial intelligence, big data analytics, and the Internet of Things (IoT), in transforming project management practices. However, it is important to note that other factors, such as Digitally Competent Employees (DF2) and Digital Transformation (DT1), have also been identified as significant enabling elements, suggesting that a comprehensive approach that integrates technology with activities that improve the workforce capability, can contribute to achieving project management success. This supports the perspective suggested in several articles [11,16,50,57] that digital infrastructure is not only about technology but also about people, leadership, competencies, and skills.

The scenario analysis conducted in this article provides insights into the validity of the final ranking under different assumptions. In Scenarios B and C, where "compliance with schedule" and "compliance with budget" were excluded, respectively, Digitally Competent Employees (DF2) rose to the top position. Additionally, the CC_i of Digital Teams (DF1) rose significantly in Scenario C when "compliance with budget" was excluded from the FTOPSIS criteria. These changes in the significance of enabling elements as well as the shifts in their positions, highlight the dynamic effect of the project management success indicators on the enabling elements, indicating that the importance of a specific element may change depending on the context, priorities, or sector of the organization. Moreover, the shift in the position of DF2 specifically highlights the critical role of employee skills and competencies in project management success, particularly when traditional project management success indicators like budget and schedule are deemed as less important criteria. Simultaneously, this highlights the role of digital tools in achieving project management success with smaller budgets and tighter schedules. Moreover, the significant improvement of the position of DF1 may indicate its important role in the digital infrastructure, contributing to project management success when complying with the budget is not a priority. These findings support several studies that emphasize the need for digital skills [11,16,50,57] and digital teams [41–43] to improve project management practices and achieve project management success.

The results have also shown that enabling elements associated with digital tools and digital fitness have always ranked higher than those associated with digital readiness. This was also shown in the estimation ranking of digital pillars based on both normalized weights and average CC_i. The lower ranking of Digital Readiness in comparison to the two other pillars might imply that the foundational readiness of an organization, while necessary, does not have the same immediate impact on project management success as much as digital tools and digital fitness do. This observation invites further research on how enabling elements associated with digital readiness could be more effectively utilized or combined with other enabling elements to enhance their impact on project management success.

Given the scarcity of research that systematically breaks down digital infrastructure into enabling elements and analyzes these elements through a structured MCA, this article has contributed to the theoretical knowledge about the pillars of digital infrastructure and their enabling elements required in an organization to improve project management practices, cope with modern organizational practices, and achieve project management success. This contribution is made in the shape of a comprehensive evaluation and ranking analysis that identifies, categorizes, and ranks these enabling elements of digital infrastructure.

From a practical standpoint, this article addresses the responsibility of organizations to focus on both the implementation of advanced digital technologies and the development of digital competencies among employees and teams. Accordingly, organizations are encouraged to adopt a balanced strategy that not only invests in technology but also strives to strengthen digital skills, empower digital teams, and enhance digital readiness to achieve project management success. Furthermore, the results of the scenario analysis indicate the need for organizations to be flexible in enforcing specific digital infrastructure, enabling elements based on the nature of the project and its specific requirements, and ensuring that their digital infrastructure strategy aligns with their identified indicators of project management success.

Finally, it is important to highlight the limitations of this analysis, especially concerning the survey respondent base. The inclusion of respondents from various industries without focusing on a specific industry has enhanced the generalizability of the results. However, the broad context and general applicability of the results can also pose a limitation, as it reduces the applicability of the results in different industries. Therefore, future research may address this by narrowing the respondent base of the survey to a particular industry. Future research may also account for specific geographical contexts in addition to specific industry contexts.

In conclusion, while the study provides a structured approach to understanding the important role of digital infrastructure in achieving project management success, the conducted scenario analysis indicated the need for further investigation into the contextual factors that may influence the ranking of the digital infrastructure enabling elements. The analysis has raised important questions about the stability of the ranking in different contexts when the weights of the criteria can change, such as the industry, the geographic location, and the respondent selection criteria. This opens doors for future research to build upon these findings and explore new ways to enhance the effectiveness of digital infrastructure in achieving project management success.

6. Conclusions

This study provides a comprehensive analysis of the digital infrastructure necessary for project management success, emphasizing the significance of three key pillars: digital readiness, digital fitness, and digital tools. Through an extensive literature review, the enabling elements of each pillar were identified, and a set of project management success indicators was established. Using a hybrid FAHP-FTOPSIS approach, an MCA was conducted to weigh and rank these enabling elements.

The results indicate that digital tools are the most important and effective enabling element of digital infrastructure. This reflects the critical role of the implementation of Industry 4.0 enabling technologies and digital transformation in the organization to enhance project management practices and achieve project management success. Digital fitness followed, highlighting the need for employees and teams in an organization to learn, train, adapt, and evolve digitally. "Digitally competent employees", as an enabling element associated with digital fitness, has been identified as the second most important enabling element of digital infrastructure among all identified elements. Digital readiness, while still essential, ranked last, suggesting that foundational preparedness, though important, must be complemented by effective tools and adaptive capabilities of teams and individuals for project management success. The ranking of digital pillars should not underestimate the importance of digital readiness as a foundation for any organization in the journey of establishing a robust digital infrastructure. Nevertheless, the two other digital pillars (digital tools and digital fitness) represent the added value for a successful digital infrastructure leading to successful project management.

Notably, the results remained consistent even when three new scenarios were proposed in the scenario analysis, whereby the weights of the MCA criteria were adjusted. This robustness highlights the reliability of the findings of this research. Despite slight changes in the final ranking of alternatives, the four enabling elements associated with digital fitness and digital tools have always ranked in the top four in all three proposed scenarios.

These findings provide valuable insights for organizations aiming to enhance their project management practices and achieve project management success through improved digital infrastructure. By prioritizing digital tools and improving digital fitness, organizations can utilize modern tools to cope with the modern project management practice, ultimately achieving greater success. Future research could explore the contextual factors that may influence the ranking of the digital infrastructure enabling elements such as the industry, the geographic location, and the survey respondent selection criteria.

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