sustainability

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Role of Digital Strategy in Managing the Planning Complexity of Mega Construction Projects

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Abstract: Background: This study investigates the potential of digital construction to enhance the planning competence of project managers in dealing with the complexities of mega construction projects. Traditional project strategies often struggle to adapt in dynamic situations, particularly evident in mega construction endeavours. Drawing inspiration from successful digital strategies in manufacturing, this research proposes that adopting digital techniques could bolster project managers' ability to navigate complexity during construction, leading to improved infrastructure delivery within budget and on schedule. Methods: Employing a quantitative approach, this study utilized an online questionnaire to gather insights from project managers. The proposed hypothesis was assessed using a one-sample *t*-test. Additionally, Pearson's correlation coefficient was employed to gauge the strength of the relationship between various constructs. This approach aimed to determine the extent to which digital construction can support effective complexity management during mega construction projects. Results: The results indicate that digital construction equips project managers with enhanced capabilities to efficiently coordinate and allocate resources in real-time within complex construction environments, thereby optimizing overall project performance. Despite these advantages, the findings also reveal that managers continue to encounter challenges overseeing numerous participants during infrastructure construction. This suggests that while digital construction contributes to improved planning against complexity, addressing the management of multiple stakeholders remains an ongoing challenge. Conclusions: This study presents a novel contribution to the construction industry by demonstrating the potential of synergizing various digital tools throughout construction processes to empower project managers in effectively addressing the complexities inherent in mega construction planning. Furthermore, it underscores how digital construction confers a dynamic advantage for project managers in navigating complexities and enhancing overall project performance.

Keywords: construction planning; information and communication technology; construction site; supply chain; technology; information management systems; BIM

Citation: Abdullahi, I.; Watters, C.; Kapogiannis, G.; Lemański, M.K. Role of Digital Strategy in Managing the Planning Complexity of Mega Construction Projects. *Sustainability* **2023**, *15*, 13809. https://doi.org/10.3390/su151813809

Academic Editors: Antonio Caggiano, Sheng Xu and Yang Yang

Received: 29 June 2023
Revised: 28 August 2023
Accepted: 8 September 2023
Published: 15 September 2023

1. Introduction

The proficiency of project managers in effectively navigating complexities inherent in large-scale infrastructure construction projects has been underscored as a critical determinant of project performance worldwide [1,2]. Complexity, which stems from multifaceted factors such as project magnitude, nature of tasks, diversity of participants, and project features, poses significant challenges and uncertainties for project managers [3,4] that could overwhelm project managers, thereby impeding their planning competency during the execution of large-scale infrastructure construction [5].

The International Centre for Complex Project Management [6] accentuates the vital role of proficient project managers in effectively planning and delivering large-scale infrastructure projects within stipulated timeframes and budgets. However, recent research indicates that project managers often grapple with managing complexities in such expansive construction projects [7,8]. Mega construction projects are often plagued by delays and cost overruns, which have become industry-recognised challenges [9]. To address these issues, there is an exigency for project managers equipped with the proficiency to handle complexities effectively.

Competence plays an instrumental role in achieving optimal performance in construction projects. Extant literature has identified competent project managers as a critical success factor for the execution of large-scale construction projects [10,11]. Therefore, the need to ensure project manager competence becomes paramount in managing complexity during mega construction execution, prompting the industry to seek strategies to bolster project managers' abilities, thereby facilitating successful project delivery.

Several recent studies propose that identifying complexity elements unique to each project type during the planning phase could serve as a strategy for managing complexity [12–14]. However, this approach does not fully reflect the dynamic nature of complexity during infrastructure construction. These studies failed to provide planning techniques that project managers could deploy to effectively handle project variables as complexities arise during construction. This knowledge gap provides the impetus for our current study to explore innovative and practical approaches to enhance project managers' planning competence in managing complexity during construction.

Planning is a fundamental competence that significantly influences project managers' success and overall project performance [15]. In line with this, the current study emphasises the importance of competent planning in managing complexity, recognising the strong correlation between planning and project success [16,17]. Ballard [18] advocated the lean last planner system as a strategy capable of bolstering planning and complexity management in construction. Concurrent engineering was suggested by Mansoor and Khalfan [19] as a potential planning strategy in construction; however, its effectiveness was undermined by prevalent poor planning techniques within the industry. Agile approaches, recommended by Masood and Farooqi [20], faced limited success due to their restricted adaptability during the construction phase to support managers when confronted with in situ complexities. Against this backdrop, our study advocates benchmarking digital manufacturing strategies to enhance project managers' planning competence in managing complexity during construction.

Integrating digital tools to craft a cohesive strategy is fast emerging as a promising approach to enhance advanced coordination among decentralised units, thereby enabling the digital engineering of products and production processes [21,22]. Furthermore, digital systems allow managers to employ simulation and modelling techniques, thus facilitating the flexible and expedient implementation of production changes in real-time [23]. Importantly, the use of digital tools in the construction industry has demonstrated considerable potential for enhancing the delivery process and promoting the development of the built environment. This novel application of technology to construction practices, termed 'digital construction', is typified by the comprehensive deployment of a variety of tools aimed at promoting safer, more efficient, and highly collaborative operations, ultimately enhancing outcomes at every stage of a project's lifecycle [24].

Despite these promising advancements, the incorporation of digital tools to develop a comprehensive digital construction strategy is still in its infancy within the construction industry [25]. This study aims to shed light on the concept of digital construction through an exploration of project managers' views on its potential to enhance daily planning processes during large-scale infrastructure construction projects. Building further on previous research, our study validates the idea that pinpointing elements of complexity during the planning phase is critical in managing the complexities that are intrinsic to construction processes. Moreover, our findings endorse the idea that project managers concur that the integration of digital construction strategies could enhance their planning abilities, allowing them to better manage construction complexities, aligning with the assertions of Wang, Chan [26]. They propose that probing the uncharted territories of large-scale construction research could provide invaluable insights for academics while equipping practitioners with novel strategies to streamline their roles, thereby fostering optimal performance in large-scale construction projects.

In today's digital age, construction tools such as BIM nD are increasingly becoming indispensable within the industry. However, examining digital construction as a competence development strategy, specifically aimed at improving planning and reducing construction complexity, has yet to be extensively explored within the construction sector. Our current study investigates the potential of digital construction to reinforce project managers' planning competence to better manage construction complexity. The findings provide compelling evidence encouraging project managers and construction firms to embrace a multitude of digital tools, leveraging the benefits of digital construction during the planning phase. We put forth the following hypotheses:

H1$_0$. *Digital construction does not augment the planning competence of project managers.*

H1$_1$. *Digital construction does augment the planning competence of project managers.*

H2$_0$. *Digital construction does not provide supportive frameworks for project managers in orchestrating planning processes for managing complexity in infrastructure construction projects.*

H2$_1$. *Digital construction does provide supportive frameworks for project managers in orchestrating planning processes for managing complexity in infrastructure construction projects.*

H3$_0$. *There is no positive correlation between the augmentation of a project manager's planning competence through digital construction and the effectiveness of digital construction in aiding project managers to plan for managing complexity during mega construction.*

H3$_1$. *There is a positive correlation between the augmentation of a project manager's planning competence through digital construction and the effectiveness of digital construction in aiding project managers to plan for managing complexity during mega construction.*

The next chapter presents a literature review on the complexities of mega construction projects, effective planning strategies, and the emerging field of digital construction. The research methodology and data analysis are discussed, followed by the presentation of findings.

2. Literature Review

2.1. Mega Infrastructure Construction Complexity

From varying professional perspectives, scholars and practitioners define megaprojects in distinct ways, with the most conventional interpretation being temporary endeavours characterised by substantial capital investment, extensive resource allocation, immense complexity necessitating high technical expertise, and a high degree of innovation. Upon completion, these projects have transformative impacts on the socioeconomic environment [27–29]. Flyvbjerg [9] characterises projects with a value exceeding a billion USD as mega, while others, like Hu, Chan [30], suggest that the project value relative to the country's GDP should determine its mega status. Van Marrewijk, Clegg [31] proposes that the project's context should determine its classification as a megaproject. This study focuses on complex infrastructure construction projects that demand significant budgets and necessitate competent, effective management to achieve strategic project objectives [32]. Such elements have been recognised in the literature as complexity components [33], which introduce challenges impeding managers' optimal performance during infrastructure development.

Baccarini [34] initially described complexity during construction as consisting of diverse interrelated parts categorised by differentiation and interdependency. Differentiation pertains to the number of varied components within a project (e.g., tasks, specialists, subsystems, parts), while interdependency refers to the level of interaction between these components. As previously discussed, these interdependent parts interact, generating challenging scenarios. Echoing this, Ma and Fu [1] define complexity during mega construction as the variation between project subsystems and the nature and volume of interactions between them. Dao, Kermanshachi [13] concurs, emphasising the crucial influence of complexity on project decision-making. Although no universally accepted definition of complexity exists [35], it is inherent that project elements interact to create complex work environments.

Abdullahi et al. [36] pinpoints task difficulty, dispersed remote teams, multiple project locations, site topography, and project scope as structural complexity indicators, creating profound difficulty during infrastructure construction. The study also identifies project duration, tempo, construction method, uncertainty in methods, project teams' capabilities, and reliance on other projects as factors contributing to uncertainty and constant change, thereby leading to chaotic situations at infrastructure construction sites. In this context, Dao, Kermanshachi [13] employed a constructive approach to explore and assess complexity via a survey of active companies in the construction industry. Factors such as physical location, project size, level of control, scope clarity, and interfaces within the project influence infrastructure projects, as does the need for an IT governance structure [37]. Mirza and Ehsan [12] identified site area, the number of elements, project participants, engineering hours, sequence rigidity, project scope, tasks, dispersed teams, and physical location as complexity elements escalating schedule constraints during large engineering projects, and Dwivedi examined the impact of stakeholder participation in the success of projects [38], an additional factor for which we were unable to control in this research.

Kermanshachi and Safapour [39] categorised complexity indicators for construction projects into stakeholder management, governance, fiscal planning, quality, legal aspects, interfaces, execution targets, design and technology, location, scope definition, and project resources. The study by Bilgin, Erol [40] identified the interaction between project features, uncertainty, and managerial competence in the work as drivers of complexity in mega construction. Kermanshachi, Rouhanizadeh [14] ranked scope definition, project resources, and a high number of project participants as the most significant complexity indicators during mega infrastructure construction.

Despite these efforts to identify complexity elements, current statistics highlighting the performance of mega infrastructure projects suggest that project managers remain unable to curtail complexity or influence construction outcomes effectively [41]. Against this backdrop, the present study posits that digital construction methodologies could enable managers to better plan for project variables and control complexity during mega infrastructure construction. Adopting digital construction could transform planning processes, empowering project managers to assert control during infrastructure construction. Consequently, this study introduces an innovative and interactive approach to construction planning. This research shares similarities with information system strategies research, looking at enterprises in developing countries [42]. However, its unique approach to examining software in mega construction and the collection of data from Nigeria provide important implications for mega construction planning in the region.

2.2. Effective Planning during Mega Infrastructure Construction

In the nascent stages of infrastructure projects, stakeholders often grapple with identifying the appropriate means to realise the project. Unsurprisingly, project managers are tasked with crafting comprehensive blueprints outlining the critical milestones and strategies necessary for achieving project objectives on schedule and within a prescribed budget [43]. This essentially captures the core responsibilities of a project manager. Zwikael [44] defined planning in construction as detailing project variables to keep the project team informed of precisely what needs to be done, the timing for these tasks, and the resources required to successfully complete the project deliverables. Executing these steps is generally more straightforward in simple construction projects than in large-scale infrastructure construction, where complexity elements interact in a way that hampers project managers' abilities to proficiently plan project variables and decide on the most suitable course of action [45]. Thus, effective planning becomes crucial to managing complexity.

Planning serves as the cornerstone of a project manager's duties during construction. Inadequate or ineffective planning has been identified as a significant precursor to infrastructure project failure, given that such projects consume vast resources, necessitating effective planning for resource utilization [16]. Gidado [46] attributed the failure of many construction projects to management's inability to devise plans adequately addressing project complexity, a notion corroborated by researchers such as Kerzner [16], Koskela and Howell [47], and El-sabek [48], among others.

According to Kerzner [16], effective planning enables the project manager to anticipate and mitigate uncertainty, enhance operational efficiency, define project objectives, and provide a framework for monitoring and controlling work. Project managers must formulate plans that fully outline these variables during the planning phase to achieve effective planning. Numerous studies have delineated the process for formulating a comprehensive project plan. Kerzner [16] emphasised scheduling, budgeting, forecasting, procedure, and standards as vital elements of construction project planning. Faniran et al. [49] pinpointed the critical success factors that influence construction project planning:

1. extensive planning before execution,
2. reduced emphasis on developing schedules for monitoring and controlling project progress,
3. an increased focus on developing an operational plan for project implementation.

However, the intricate nature of mega infrastructure construction projects often impedes project managers from defining the project plan and its encompassing processes. For example, factors such as the multitude of tasks, scope uncertainty, diversity of drawings, and scope ambiguity constitute elements of complexity in infrastructure construction, potentially obstructing project managers from proficiently planning such projects. Effective planning is the linchpin of successful infrastructure delivery and a fundamental project management aspect [50]. Yet, this study underscores how project managers can plan infrastructure projects within complex and dynamic environments like mega construction sites where project characteristics are minimally understood at project inception.

Baldwin and Bordoli [51] underscore the importance of project managers using systematic and logical methods and techniques when crafting the project plan to ensure its effectiveness. Moreover, construction management challenges amplify complexities that are predominantly encountered on the construction site during infrastructure development [52]. Martins, Evangelista [53] proposed that effective planning could be attained through BIM-enabled computing software to assist project managers in designing and delineating project variables. However, Lock [54] opines that software used during construction is counterproductive, as project managers are preoccupied with numerous responsibilities and often have scant time to interact with the software. In construction, software is an integral component of the digital toolset that comprises the digital construction paradigm. Therefore, there exists no distinction between these two concepts. The term "software" specifically pertains to digital instruments employed in construction-related endeavours, whereas "digital tools" represent a more comprehensive categorisation of all technology-based resources utilised throughout the construction process, thereby encapsulating the digital construction philosophy.

Against this backdrop, the current study posits that digital construction could empower project managers to effectively plan infrastructure construction projects. This approach is more engaging as managers are not overburdened with software but can instead incorporate additional digital tools to complement any shortcomings of the other. Consequently, this study hypothesised that construction managers concur that digital construction effectively facilitates their planning of infrastructure construction. This is tested through Hypothesis 1 and its sub-hypotheses and Hypothesis 2, as depicted in Figure 1.

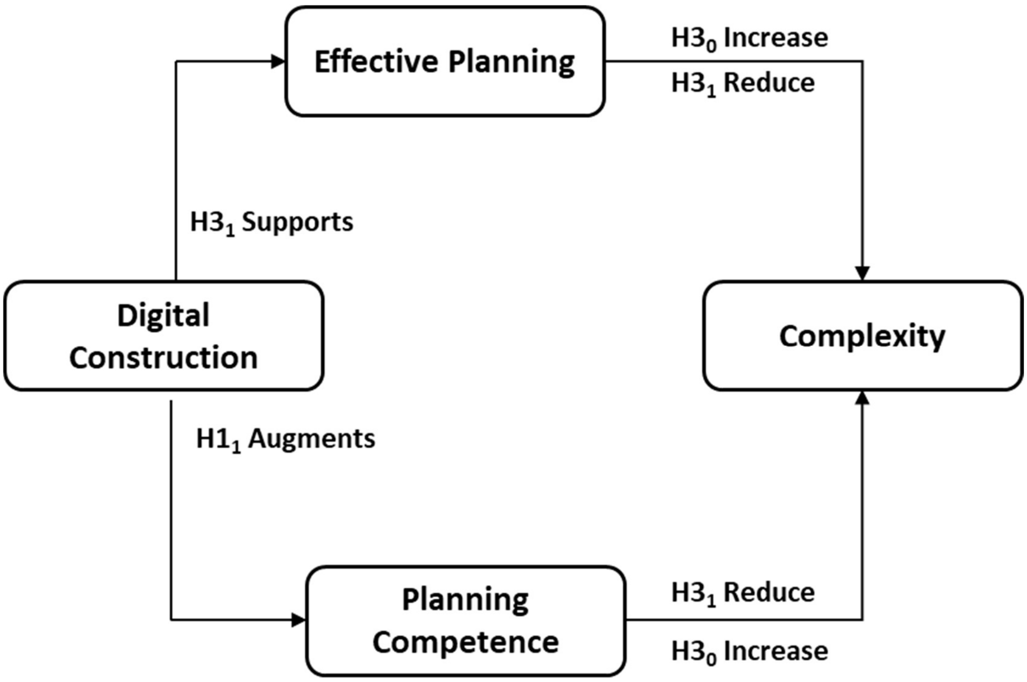

Figure 1. Proposed conceptual framework showing hypothesised relationships.

H1.1$_0$. *Digital construction does not enable managers to explore different planning approaches to manage sequence rigidity during construction.*

H1.2$_0$. *Digital construction does not permit managers to breakdown project scope into more workable components.*

H1.3$_0$. *Digital construction constraints managers from scheduling workers on every project size.*

H1.4$_0$. *Digital construction does not enable project managers to forecast resources required during construction through an accurate budget estimation.*

H1.5$_0$. *Digital construction does not support managers to implement measures to achieve defined quality objectives when unfamiliar construction methods are used.*

H1.6$_0$. *Digital construction does not provide managers with a platform to monitor the project's vast supply chain during mega infrastructure construction.*

H2$_0$. *Digital construction does not augment the project manager's planning competence.*

2.3. Digital Construction for Mega Infrastructure Construction Planning

Technological advancements have consistently reshaped operational processes across diverse industries. The construction sector is no exception, as evidenced by the evolution of Building Information Modelling (BIM) nD models and collaborative software for construction planning over the past decade. While feedback from the use of these individual tools during planning has been positive, a significant challenge has been the project managers' limitations in utilising these tools during the construction stage [55]. The deployment of BIM nD during construction planning was often perceived as limited, and in many instances, the interoperability of the tools was deemed impractical [56]. The synergistic use of various tools in manufacturing has proven crucial in supporting managers, prompting this study to explore whether a similar approach could enhance project managers' planning competence for managing complexity during construction.

The combination of numerous tools has been reported to further enhance project planning during construction. An exemplary study by Wang, Love [57] proposed a framework integrating a BIM 3D information model and augmented reality, enabling project managers to monitor and coordinate on-site construction activities. The study suggested that project managers could effectively plan and coordinate resource allocation on construction sites by integrating tracking and sensing technologies such as Radio Frequency Identification (RFID) and laser pointing sensors. AlSaggaf and Jrade [58] introduced the ArcSPAT model, designed to help project managers navigate construction complexities and design site layouts mirroring the actual construction site. The system was developed by merging BIM to offer nD visualisation of the project site and GIS to deliver spatial presentations, thereby facilitating equipment route planning and scheduling within the construction space. Research indicated that equipment location, scheduling, and usage delegation are significant aspects of task complexity in large engineering projects [59].

Kim and Chi [60] proposed a multi-camera vision-based productivity monitoring methodology to aid project managers in coordinating machinery for earthmoving projects. The system compiled and matched image data from multiple on-site camera sources via single-camera vision-based equipment. The collated data assisted project managers in assessing equipment productivity and deciding on its optimal usage to maximise on-site operational capacity. Furthermore, Irizarry, Karan [61] proposed a construction supply chain management framework that combines 3D information modelling and geographic information systems (GIS) to create a system enabling managers to visualise supply chain status and provide early warning signals on material delay, ensuring the timely delivery of materials on-site during construction.

Guo, Jahren [62] adopted a case study approach to demonstrate how the application of nD modelling, GIS, Light Detecting and Ranging (LIDAR), Automatic Machine Guidance (AMG), intelligent compaction, and mobile devices are revolutionising planning processes for transportation projects. They showed how managers could better plan such projects by relying on a combination of digital tools called ‘digital construction’. Similarly, Abdullahi, Kapogiannis [63] reported on project managers integrating multiple digital tools as a strategic approach to managing infrastructure complexity during construction.

Given this evidence supporting the use of digital tools to aid project managers’ planning, it is compelling for professional project managers to adopt digital construction on-site further, as this approach could augment their planning competence and thus ensure successful mega infrastructure delivery. Following this reasoning, this study proposes Hypothesis 3: A positive relationship exists between digital construction augmenting project managers’ competence and digital construction aiding project managers to plan effectively against complexity during mega construction. Establishing this correlation would suggest that digital construction could empower project managers to augment their competence to manage complexity that impedes planning during mega infrastructure construction.

Hence, in the intricate landscape of infrastructure projects, early stages demand optimal approaches for realization. Here, project managers shoulder the responsibility of crafting cohesive blueprints that align with objectives, budget, and deadlines [40]. Within this context, Zwikael [41] underscores construction planning’s importance, encompassing meticulous project variable detailing and resource requirements, critical in complex large-scale projects where complexity can hinder efficient planning [42]. Inadequate planning has been a key contributor to infrastructure project failures [16], attributed to an inability to address complexity [64], a view reinforced by experts such as Kerzner [16], Koskela and Howell [65], and El-sabek [66]. Effective planning, according to Kerzner [16], curbs uncertainty, streamlines efficiency, and defines objectives.

Nevertheless, mega infrastructure projects, marked by intricate tasks, scope ambiguities, and diverse needs, often challenge efficient planning. This study spotlights digital construction as a strategy empowering project managers in effective planning, presenting an innovative solution to manage complexities in mega construction. The research explores digital construction’s impact on planning competence [H1.1–H1.6], culminating in the overarching hypothesis [H2], positioning digital construction as a dynamic tool for navigating intricate construction scenarios. Amid technological strides, the construction sector has witnessed BIM nD models and collaborative software’s evolution for planning. Integrating these tools remains a challenge, inspiring this study to explore enhancing project managers' planning for complexity management by developing soft skills such as proactive behaviour [67]. Examples include BIM-augmented reality integration, multi-camera productivity monitoring, and BIM-GIS supply chain fusion, collectively known as 'digital construction', see hypothesis [H3]. Acknowledging digital tools' planning role, the study suggests on-site digital construction's potential to enhance competence, fostering successful mega infrastructure delivery and a positive link between digital construction's augmentation and effective complexity management during mega construction.

3. Research Methodology

This study employed a sequential explanatory approach, chosen for its ability to foster a pragmatic approach to survey design, thereby mirroring the practical realities of construction. Such a method permits participants to quantify their responses and enables researchers to systematically draw inferences from the data to support or refute the proposed hypotheses [68]. While a qualitative approach might have provided further insights, it is recognised that each project manager has unique perspectives on digital construction on-site during the planning phase of mega construction projects. Consequently, the sequential explanatory design, frequently utilised in construction management research [69], was deemed the most suitable.

The initial phase of the study involved identifying complexity elements hindering project managers from proficiently planning mega infrastructure construction. The literature examining the integration of multiple digital tools to enhance project managers' planning competence during infrastructure construction was also scrutinised. Based on these findings, a focus group was convened, comprising 13 built-environment professionals with prior experience in constructing mega infrastructure. The group selection was purposive, ensuring the participation of individuals possessing the necessary characteristics. This group included five academics, two postgraduate students, three lecturers, and eight construction project managers. Among the group were four civil engineers, two architects, one geospatial engineer, and one building engineer.

The theoretical concepts of complexity, construction planning, and digital construction were presented, and the group was tasked with determining the relationship among these variables in order to develop a questionnaire reflecting on-site construction scenarios. The focus group aimed to bridge this gap because theoretical concepts do not always reflect actual practice. The questionnaire sought to establish project managers' perspectives on digital construction, enhancing their planning competence to manage infrastructure complexity.

Prior to widespread deployment, a pilot study was conducted with a threshold of ten participants [70]. In-person paper questionnaires were distributed to 17 project managers on mega construction sites, including ten civil engineers, three architects, three building engineers, and one structural engineer. Their consent to participate was obtained after explaining the concepts of complexity and digital construction. The pilot study ensured the elimination of repetitiveness, ambiguity, and redundancy from the final version of the questionnaire, which was then deployed online using Qualtrics. The first section of the questionnaire defined the concept of digital construction and requested participation only from those familiar with using digital tools during infrastructure construction. It also collected demographic data. In the subsequent section, questions based on the proposed hypothesis sought to ascertain project managers' agreement with the assertion that digital construction could enhance their planning competence to manage complex infrastructure construction.

Project managers were asked to rate the influence of digital construction on their planning competence during construction on a seven-point Likert scale (0 indicating no influence and 7 indicating significant influence). The same scale was utilised to establish their agreement that digital construction enables them to effectively plan for complexity management in infrastructure construction—with 0 indicating total disagreement and 7 indicating complete agreement. Likert scales have been used in comparable studies exploring construction practices on construction sites, as shown by Luo, He [32], Dao, Kermanshachi [13], and Mirza and Ehsan [12], making it practicable in this study context.

This research centred on the Nigerian context, which does not limit its relevance as project managers and construction companies involved in mega infrastructure development often have global outreach, rendering the study's findings generalizable to mega construction projects worldwide. Furthermore, previous research suggests that management practices from developing countries can be successfully applied in the context of developed economies [71]. A potential limitation lies in the number or efficacy of tools used by individual managers could influence their responses, a factor that the current study, due to its questionnaire methodology, could not determine. However, participants were advised to refrain from participating if they lacked digital construction experience.

3.1. Data Collection

This study's methodological approach was grounded in applying a homogenous sampling strategy, recognised for its capacity to purposefully present a study sample with analogous characteristics [72]. This sampling technique was instrumental in ensuring the chosen sample was equipped to accurately delineate the impact of digital construction on project managers' competence, hinged on their collective experience of working on similar project types. The questionnaire for this study targeted 211 project managers (N = 211) registered with the Federation of Construction Industry (FOCI) in Nigeria. A comprehensive overview of the research context was provided in the introductory segment, with a clear recommendation that only participants with the necessary experience in utilising digital tools during mega infrastructure development should partake in the study.

In light of the distribution method employed, establishing the exact number of individuals who received the questionnaire link presented a challenge. Nonetheless, 152 responses were logged from a total of 211 registered FOCI project managers, reflecting a favourable response rate of 72%, considered an excellent benchmark for an online questionnaire survey [73]. The range of industry experience amongst respondents spanned 6-30 years, with a substantial majority (71%) possessing over ten years of professional experience. Civil engineers represented the most prominent professional category amongst respondents (48%), reflecting a global trend observed on mega construction projects attributed to the extensive operational footprint of companies capable of executing such large-scale projects. This pattern of professional representation was corroborated by comparable studies by Bosch-Rekveldt, Jongkind [74] and Ahn, Shokri [75] in Europe and the USA, respectively. Regarding reliability, Cronbach's alpha coefficient registered at 0.790, signalling a high level of internal consistency and demonstrating that the study's findings could be reliably reproduced within similar research contexts [76].

3.2. Data Analysis

The study adopted a descriptive statistical approach to present demographic findings, encapsulating data frequency and percentage distributions. Inferential statistics were employed in the second section, using a one-sample *t*-test to test the first two hypotheses. The one-sample *t*-test is often used when the objective is to ascertain whether the mean (μ) of the sample population differs significantly from a hypothesised value of relevance [77]. This statistical technique is effective in endorsing the responses gathered from a sample as a credible representation of the wider population. Particularly relevant for this study, given the varied individual opinions on digital construction among project managers, the one-sample *t*-test provides robust statistical power due to its assumption of normal distribution of the dependent variable within the population and the independence of each data point [78].

In the context of hypothesis testing, any value H_0: $\mu 1 \leq 4$ is considered indicative of digital construction having no significant influence on project management planning competence, while H1: $\mu 1 > 4$ is interpreted as the adoption of digital construction augmenting project management planning competence. Any value where $y \geq 4$, with the hypothesised test value of 4 for the one-sample *t*-test, is deemed to signify a high level of influence and thus is accepted by the researchers.

If the calculated t of y $\geq$ 1.6558 represents the one-tailed critical t at the 95% confidence level, the researchers reject the null hypothesis. This threshold ensures a high degree of certainty that the findings did not occur by chance or as an outcome of sampling error. As illustrated in Table 1, project managers generally agreed that digital construction enhances their planning competence during infrastructure construction, with the most substantial influence being the ability to estimate the budget and forecast the required resources accurately. The least influential factor was the ease of scheduling workers, regardless of the overall size of the project site, though the finding remains statistically significant.

Table 1. Shows descriptive statistics and one-sample *t*-test findings for H1 and H2.

H	Construct	Mean	SD	$t \geq 4$	Sig	Remark
H1.1$_1$	Explore different planning approaches to manage sequence rigidity during construction	4.94	0.136	6.932	<0.001	Accepted
H1.2$_1$	Breakdown the project scope into more workable components	4.91	0.167	5.476	<0.001	Accepted
H1.3$_1$	Easily schedule workers irrespective of the project site's overall size	4.72	1.830	4.649	<0.001	Accepted
H1.4$_1$	Forecast resources required during construction by accurately estimating the budget	6.13	0.992	25.474	<0.001	Accepted
H1.5$_1$	Implement measures to achieve defined quality objectives when using unfamiliar construction methods	5.43	1.104	15.410	<0.001	Accepted
H1.6$_1$	Provides a platform to monitor the project's vast supply chain	5.80	1.191	17.967	<0.001	Accepted
H2.0$_1$	Digital Construction Influence on project manager's planning competence	6.02	1.668	28.648	<0.001	Accepted

$p \leq 0.05\ \alpha$.

The association between the influence of digital construction and each construct underlying effective construction planning was examined through *Pearson's r correlation*, as delineated in Table 2. A multiple regression analysis was subsequently utilized to scrutinize the cumulative correlation of these constructs against the influence of digital construction, thereby determining if digital construction could comprehensively enhance construction managers' planning competence. Concretely, if the influence of digital construction demonstrates a positive correlation with the construct in the linear test, it could be inferred that digital construction potentially bolsters project managers' capability to manage complexity concerning the specified construct detailed in Table 1. Further, if an overall positive relationship exists between digital construction and the constructs, it can be deduced that digital construction unequivocally augments project managers' planning competence to navigate construction complexity.

Table 2. Highlights regression analysis findings for the relationship between $H1_1$ and $H2_1$.

H3	Independent Variable	Regression Output						
		Model Summary			ANOVA		Coefficients	
		R	R^2	Adjusted R^2	*F*	Sig	*t*	Sig
$H3.1_1$	Explore different planning approaches to manage sequence rigidity during construction	0.353	0.124	0.118	19.725	<0.001	4.441	<0.001
$H3.2_1$	Breakdown the project scope into more workable components	0.492	0.242	0.237	44.472	<0.001	6.669	<0.001
$H3.3_1$	Easily schedule workers irrespective of the project site's overall size	0.347	0.121	0.114	19.0.56	<0.001	4.365	<0.001
$H3.4_1$	Forecast resources required during construction by accurately estimating the budget	0.397	0.157	0.151	25.932	<0.001	5.092	<0.001
$H3.5_1$	Implement measures to achieve defined quality objectives when using unfamiliar construction methods	0.346	0.120	0.114	18.964	<0.001	4.355	<0.001
$H3.6_1$	Provides a platform to monitor the project's vast supply chain	0.410	0.168	0.162	28.032	<0.001	5.295	<0.001
	Multiple Regression Output	**0.627**	**0.393**	**0.351**	**9.429**	**<0.001**		

$p \leq 0.05\ \alpha$.

The strength of the relationship discerned from Pearson's correlation coefficient was interpreted in line with the gamma coefficient, as presented in Table 3. The statistical significance of Pearson's r was ascertained using a *t*-test to validate significance, as indicated in Table 2. Significance was confirmed when the calculated *t*-value was greater or equal to 1.6558, representing the one-tailed critical t, a threshold set to ensure that the research objective was adequately addressed.

Table 3. Pearson's r coefficient interpretation (adopted from [79]).

Measure	Interpretation
0	No association
0.01–0.09	Negligible association
0.10–0.29	Low association
0.30–0.59	Moderate association
0.60–0.74	Strong association
0.75–0.99	Very strong association
1.00	Perfect association

4. Results and Discussion

The results in Table 1 present the one-sample *t*-test for H1 and H2. The calculated *t*-values for the sub-hypotheses collectively were significantly higher than the critical *t*-value and the *p*-values were below 0.05, leading to the rejection of the null hypotheses. This demonstrates significant differences between the observed and expected means, indicating that project managers perceive digital construction as valuable for managing complexity in resource allocation, cost control, and timely instruction distribution during mega construction projects. This finding supports the idea that project managers are better equipped to schedule workers, forecast resources, and monitor the supply chain when utilizing digital construction during mega construction in Nigeria.

The regression analysis in Table 2 investigated the relationships between the independent and dependent variables, representing the influence of digital construction on project managers' planning. The overall regression model yielded an R-squared value of 0.393, indicating that approximately 39.3% of the variance in the dependent variable can be explained by the independent variables considered collectively. The coefficient of determination (R^2) indicates the proportion of variance in project managers' competence that the independent variables can explain. For each dimension of planning competence (H3.1b, H3.2b, H3.3b, H3.4b, H3.5b, H3.6b), the R^2 values range from 0.120 to 0.242, suggesting that the independent variables account for 12.0% to 24.2% of the variance in project managers' competence. The adjusted R^2 values, considering the number of predictors, range from 0.114 to 0.237.

The F-statistic tests the overall significance of the regression model, ranging from 18.964 to 44.472, all of which were statistically significant, with *p*-values < 0.001. These results indicate that the regression models have a significant overall fit, suggesting that the independent variables collectively contribute to explaining project managers' planning competence in managing complexity. The *t*-tests assess the individual significance of each independent variable. For each competence dimension, the *t*-values range from 4.355 to 6.669, all statistically significant, with *p*-values < 0.001. These findings indicate that each independent variable significantly and positively impacts project managers' competence in managing complexity. The multiple regression analysis demonstrates that the independent variables related to different dimensions of competence significantly contribute to explaining project managers' overall planning competence in managing complexity.

4.1. Digital Construction Strategy

The study examined the relationship between digital construction and project managers' competence in planning mega construction projects. The findings demonstrated a statistically significant positive correlation between digital construction and individual constructs. A multiple regression analysis further confirmed a strong relationship between digital construction and the constructs, particularly concerning recent advancements in construction scheduling tools. Notably, H3.2 showed the most robust Pearson's r coefficient, likely attributed to these advancements.

The integration of scheduling tools with 3D models, facilitated by Virtual Design and Construction's (VDC) 4D BIM features, has empowered project managers to effectively handle complex project scopes by decomposing them into manageable components [80]. This integration also allows for the exploration of multiple planning strategies, mitigating the complexity arising from sequence rigidity [81]. However, despite the extensive use of planning software in construction organizations, underwhelming success rates in mega infrastructure construction highlight the potential for enhancing project success by complementing such software with various tools. These additional tools enable project managers to disaggregate extensive project scopes into work packages and simulate feasible planning approaches throughout the project lifecycle, as outlined in sub-hypothesis H3.2.

The success of digital construction in improving planning processes is evident in studies such as AlSaggaf and Jrade [58], who achieved overwhelming success in site layout planning using digital construction concepts. Similarly, Wang, Love [57] proposed a synergistic approach by combining BIM 3D models with AR headsets, allowing project managers to simulate on-site resource schedules. These examples highlight how the integration of digital tools enhances project managers' competence, enabling them to achieve a balanced workload and personal equilibrium for effective work scheduling.

Furthermore, the integration of digital tools enables project managers to optimally utilize and schedule on-site workers, as demonstrated in the sub-hypothesis H3.3. Kim and Chi [60] successfully integrated BIM 4D and 5D simulation features with a site webcam, resulting in an innovative project schedule management system. Managing project scope is a critical determinant of success in mega construction projects. Therefore, project managers must leverage digital construction to effectively handle the overwhelming scope of mega infrastructure projects [39,59].

Comprehensive planning is necessary to appropriately schedule workers, allocate materials, and define quality objectives in managing the scope of mega infrastructure projects. Resource planning is considered a critical success factor for construction management. This study reveals that project managers acknowledge the role of digital construction in enhancing their planning competencies for mega infrastructure projects. The amalgamation of digital tools enables project managers to respond effectively to challenges and uncertainties, facilitating their workflow within the project environment.

The integration of 4D BIM and virtual reality enables project managers to plan effectively for light steel construction, enhancing planning efficiency and improving productivity during construction [82]. Additionally, Wang, Wang [83] proposed incorporating blockchain technology to facilitate real-time control and resource scheduling during precast construction, a primary element of mega infrastructure projects. Digital construction facilitates efficient resource utilization in the face of extensive construction sites, numerous participants, and considerable resources [5]. Further, incorporating GIS into 3D virtual models enables project managers to consider site topography and existing facilities when formulating construction plans [84], ensuring project tempo is maintained during construction.

Through constructs H3.3, H3.4, and H3.6, the study empirically aligns with previous research by affirming that digital construction enables project managers to schedule and optimize resource usage on-site, ultimately enhancing their competence in planning mega infrastructure projects. Moreover, the investigation corroborates the potential of digital construction to address supply chain inconsistencies during the construction phase, a factor influenced by insufficient planning by project managers. The vast scope of mega infrastructure projects necessitates managers to interact with an extensive array of suppliers and subcontractors, and the role of supply chain management in handling the intricate networks intrinsic to mega construction projects cannot be discounted [85,86].

While the last planner system has been suggested as a strategy to manage the construction supply chain, its scalability to mega infrastructure projects is limited primarily to housing construction. In response, Vrijhoef [87] proposed the use of an information-driven system to enhance information sharing among construction supply chains, contributing to project success. Magill, Jafarifar [88] highlighted the effectiveness of 4D BIM in supporting the Integrated Construction Supply Chain Logistics System (ICSCL), which could optimise the interaction between personnel, materials, and equipment for efficient construction planning.

The advancement of geographical systems and sensing technology has empowered construction firms to visualise and plan their supply chain, enabling construction project managers to interact with the project and its personnel in real time. Consequently, the findings from sub-hypothesis H3.6 reflect past studies and give credibility to the integration of digital tools to augment project managers' ability to visualise and integrate the project supply chain during construction. This approach could enhance productivity, improve timely project delivery, and reduce waste, thereby influencing completion within the allocated budget. Based on this perspective, sub-hypothesis H3.6 rejects the null hypothesis.

The findings reveal that digital construction significantly provides project managers with a platform to deconstruct and distribute the project scope into manageable components, thereby effectively managing the extensive supply chain associated with the project. A broad adoption of digital construction on construction sites can support project managers in enhancing their planning competence and addressing the inherent complexities of large-scale infrastructure projects. This confirmation aligns with the growing body of literature that emphasizes the critical role of digital construction in improving project planning, competence augmentation, and the overall success of mega infrastructure projects.

4.2. Policy Implications

As mega projects are related to infrastructure and ordinarily involve large expenditures of public funds, the results are significant for policymakers in establishing regulations to reduce the costs and risks associated with construction of these projects. However, policies should encourage the adoption of technology as it advances and not entrench rules that only reflect the currently available tools. Recent developments in artificial intelligence make its integration into construction monitoring and management a near certainty, and blockchain technology [89], which is increasingly used in logistics [83,90–92] and record keeping in many industries, can serve as a transparent mechanism record and facilitate processes, thereby increasing transparency [93].

Further, the existence of regulation can hinder or promote the use of digital construction with policies encouraging use of technologies discussed here, improving project management. Whether through formal regulation or soft law, standardization in the use of digital construction technologies should foster adoption more broadly. As mega infrastructure projects require unique expertise, research on the extent of the expertise of the same individuals is leveraged globally [94], or if expertise is predominately localized, adds a cross-border element and signals the need for transnational standards. The need may be partially addressed by advanced local hubs, such as the BIM e-submission requirements in Singapore [64,65], a jurisdiction that often leads to regulatory innovation. Any standards must address data security and the treatment of private data, especially with the use of cloud-based technology and protecting intellectual property rights. Digital construction can facilitate the establishment and monitoring of standards that attenuate negative environmental impacts and injury risks along with cost accountability. Industry standards are often more effective and adaptive than formal regulations, but government policies can also informally impact attitudes [66]. In addition to policies that may have a legal effect [95,96], consensus-based standards, such as the National BIM Standard (NBIMS-US) and the work of the EU BIM Tak Group [67], may establish these frameworks. These standards can either evolve formally or gradually emerge over time, yet they must remain flexible enough to accommodate technological shifts; a domain where project managers might exhibit a sluggish response while businesses are compelled to promptly address the matter out of necessity [97], with consequential effects on decision makers.

5. Conclusions

In the realm of construction management, meticulous planning stands as an indispensable cornerstone, and the repercussions of inadequate planning on the success of infrastructure projects, particularly those of a grand scale, are widely acknowledged. This study resonates with researchers' observations that project failures often stem from a lack of comprehensive planning to address inherent complexities. Extending the discourse, this research significantly contributes by empirically substantiating the capacity of digital construction to amplify project managers' planning competence, thereby effectively mitigating the intricate challenges arising from complexity in mega infrastructure construction. The study introduces an innovative methodology for construction project managers and entities to elevate their planning processes through the strategic assimilation of digital tools, fostering optimal resource allocation and empowering managers to adeptly navigate the labyrinthine landscape of construction complexity, consequently forging a pathway towards enhanced project optimization. Furthermore, it underscores the educational implications of infusing digital tool proficiency within the curriculum for aspiring construction project managers.

While predominantly focused on the project execution phase, acknowledged as a nexus of complex management intricacies, the study's broader objective encompassed the evaluation of digital construction's viability in holistically addressing complexity throughout the project lifecycle. Although the study is situated within the context of mega infrastructure construction in Nigeria, its implications reverberate across the global spectrum, resonating with project managers and construction firms engaged in large-scale infrastructure endeavours. The study acknowledges the potential influence of the variety and proficiency of digital tools adopted by individual managers on their responses, a facet partially addressed within the survey-based methodology.

It is pertinent to note that the study made diligent efforts to ensure the inclusion of experienced digital construction practitioners. As a reflection on methodology, future inquiries may delve into alternative frameworks to glean deeper insights into the intricate interplay through which digital construction empowers project planning. Additionally, a broader research trajectory could encompass diverse stakeholders within the built environment, encapsulating the panorama of mega infrastructure construction, thereby furnishing a comprehensive and robust comprehension of digital construction's role in adeptly managing complexity.

Author Contributions: Conceptualization: I.A.; methodology, I.A., M.K.L. and G.K.; formal analysis, I.A. and G.K. data curation, I.A.; writing—original draft preparation, I.A., C.W., G.K. and M.K.L.; writing—review and editing, C.W., M.K.L., I.A. and G.K.; funding acquisition, I.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded in part by CGC Nigeria Ltd.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the faculty research committee of Nottingham University Business School, China.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data available upon request.

Acknowledgments: The authors thank CGC Nigeria Ltd. for their financial support and FOCI members' willingness to participate in the study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ma, L.; Fu, H. Exploring the influence of project complexity on the mega construction project success: A qualitative comparative analysis (QCA) method. *Eng. Constr. Archit. Manag.* **2020**, *27*, 2429–2449. [CrossRef]
2. Yap, J.B.H.; Shavarebi, K. Enhancing project delivery performances in construction through experiential learning and personal constructs: Competency development. *Int. J. Constr. Manag.* **2019**, *22*, 1–17. [CrossRef]
3. Nikolić, M.; Cerić, A. Classification of Key Elements of Construction Project Complexity from the Contractor Perspective. *Buildings* **2022**, *12*, 696. [CrossRef]
4. Aliu, J.; Oke, A.E.; Kineber, A.F.; Ebekozien, A.; Aigbavboa, C.O.; Alaboud, N.S.; Daoud, A.O. Towards a New Paradigm of Project Management: A Bibliometric Review. *Sustainability* **2023**, *15*, 9967. [CrossRef]
5. Nguyen, L.D.; Le-Hoai, L.; Tran, D.Q.; Dang, C.N.; Nguyen, C.V. Effect of project complexity on cost and schedule performance in transportation projects. *Constr. Manag. Econ.* **2018**, *37*, 384–399. [CrossRef]
6. International Centre for Complex Project Management. *Complex Project Manager Competency Standards*; Commonwealth of Australia, Department of Defence: Canberra, Australia, 2012.
7. Ghaleb, H.; Alhajlah, H.H.; Bin Abdullah, A.A.; Kassem, M.A.; Al-Sharafi, M.A. A scientometric analysis and systematic literature review for construction project complexity. *Buildings* **2022**, *12*, 482. [CrossRef]
8. Zarei, B.; Sharifi, H.; Chaghouee, Y. Delay causes analysis in complex construction projects: A semantic network analysis approach. *Prod. Plan. Control.* **2018**, *29*, 29–40. [CrossRef]
9. Flyvbjerg, B. *The Oxford Handbook of Megaproject Management*; Oxford University Press: Oxford, UK, 2017.
10. Shayan, S.; Pyung Kim, K.; Tam, V.W. Critical success factor analysis for effective risk management at the execution stage of a construction project. *Int. J. Constr. Manag.* **2019**, *22*, 1–8. [CrossRef]
11. Ghanbaripour, A.N.; Golmoradi, M.; Langston, C.; Skulmoski, G.; Arqoub, M.A. The effect of project manager's management style on project delivery success in construction projects. *Int. J. Constr. Manag.* **2020**, *22*, 2941–2950. [CrossRef]
12. Mirza, E.; Ehsan, N. Quantification of project execution complexity and its effect on performance of infrastructure development projects. *Eng. Manag. J.* **2017**, *29*, 108–123. [CrossRef]
13. Dao, B.; Kermanshachi, S.; Shane, J.; Anderson, S.; Hare, E. Exploring and assessing project complexity. *J. Constr. Eng. Manag.* **2017**, *143*, 04016126. [CrossRef]
14. Kermanshachi, S.; Rouhanizadeh, B.; Dao, B. Application of Delphi Method in Identifying, Ranking, and Weighting Project Complexity Indicators for Construction Projects. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2020**, *12*, 04519033. [CrossRef]
15. Moradi, S.; Kähkönen, K.; Aaltonen, K. Comparison of research and industry views on project managers' competencies. *Int. J. Manag. Proj. Bus.* **2020**, *13*, 543–572. [CrossRef]
16. Kerzner, H. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*; John Wiley & Sons: Hoboken, NJ, USA, 2017.
17. Abou-Ibrahim, H.; Hamzeh, F.; Zankoul, E.; Munch Lindhard, S.; Rizk, L. Understanding the planner's role in lookahead construction planning. *Prod. Plan. Control.* **2019**, *30*, 271–284. [CrossRef]
18. Ballard, H.G. The Last Planner System of Production Control. Ph.D. Thesis, University of Birmingham, Birmingham, UK, 2000.

19. Mansoor, M.; Khalfan, A. *Benchmarking and Readiness Assessment for Concurrent Engineering in Construction (BEACON)*; Loughborough University: Loughborough, UK, 2001.
20. Masood, Z.; Farooqi, S. Benefits and key challenges of agile project management under recent research opportunities. *Int. Res. J. Manag. Sci.* **2017**, *5*, 20–28.
21. Theorin, A.; Bengtsson, K.; Provost, J.; Lieder, M.; Johnsson, C.; Lundholm, T.; Lennartson, B. An event-driven manufacturing information system architecture for Industry 4.0. *Int. J. Prod. Res.* **2017**, *55*, 1297–1311. [CrossRef]
22. Zhang, J.; Chen, Y.; Wang, D.; Zhang, Y. Learning in MTS of Construction Megaproject: A Conceptual Framework. *Sustainability* **2023**, *15*, 4295. [CrossRef]
23. Brettel, M.; Friederichsen, N.; Keller, M.; Rosenberg, M. How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. *Int. J. Mech. Ind. Sci. Eng.* **2014**, *8*, 37–44.
24. Catlin, T.; Laberge, L.; Varney, S.; Bradley, C.; Hirt, M.; Smit, S. Digital Strategy: The Four Fights You Have to Win. *McKinsey Quarterly*, 18 October 2018; 78–89.
25. Wernicke, B.; Stehn, L.; Sezer, A.A.; Thunberg, M. Introduction of a digital maturity assessment framework for construction site operations. *Int. J. Constr. Manag.* **2021**, *23*, 898–908. [CrossRef]
26. Wang, T.; Chan, A.P.; He, Q.; Xu, J. Identifying the gaps in construction megaproject management research: A bibliographic analysis. *Int. J. Constr. Manag.* **2020**, *29*, 1585–1596. [CrossRef]
27. Kardes, I.; Ozturk, A.; Cavusgil, S.T.; Cavusgil, E. Managing global megaprojects: Complexity and risk management. *Int. Bus. Rev.* **2013**, *22*, 905–917. [CrossRef]
28. Tan, W.; Tiong, R. Managing Sustainable Megaprojects along China's New Silk Roads. *Sustainability* **2023**, *15*, 4042. [CrossRef]
29. Yusuf, N.; Abdulmohsen, D. Saudi Arabia's NEOM Project as a Testing Ground for Economically Feasible Planned Cities: Case Study. *Sustainability* **2023**, *15*, 608. [CrossRef]
30. Hu, Y.; Chan, A.P.; Le, Y.; Jin, R.-Z. From construction megaproject management to complex project management: Bibliographic analysis. *J. Manag. Eng.* **2013**, *31*, 04014052. [CrossRef]
31. Van Marrewijk, A.; Clegg, S.R.; Pitsis, T.S.; Veenswijk, M. Managing public–private megaprojects: Paradoxes, complexity, and project design. *Int. J. Proj. Manag.* **2008**, *26*, 591–600. [CrossRef]
32. Luo, L.; He, Q.; Jaselskis, E.J.; Xie, J. Construction project complexity: Research trends and implications. *J. Constr. Eng. Manag.* **2017**, *143*, 04017019. [CrossRef]
33. Ninan, J.; Clegg, S.; Burdon, S.; Clay, J. Reimagining Infrastructure Megaproject Delivery: An Australia—New Zealand Perspective. *Sustainability* **2023**, *15*, 2971. [CrossRef]
34. Baccarini, D. The concept of project complexity—A review. *Int. J. Proj. Manag.* **1996**, *14*, 201–204. [CrossRef]
35. Bakhshi, J.; Ireland, V.; Gorod, A. Clarifying the project complexity construct: Past, present and future. *Int. J. Proj. Manag.* **2016**, *34*, 1199–1213. [CrossRef]
36. Abdullahi, I.; Lemanski, M.K.; Kapogiannis, G.; Jimenez-Bescos, C. Identifying and assessing complexity emergent behaviour during mega infrastructure construction in Sub-Saharan Africa. *Entrep. Bus. Econ. Rev.* **2022**, *10*, 8–22. [CrossRef]
37. Luftman, J.; Ben-Zvi, T.; Dwivedi, R.; Rigoni, E.H. IT Governance: An alignment maturity perspective. *Int. J. IT Bus. Alignment Gov. (IJITBAG)* **2010**, *1*, 13–25. [CrossRef]
38. Dwivedi, R.; Dwivedi, P. Role of stakeholders in project success: Theoretical background and approach. *Int. J. Financ. Insur. Risk Manag. XI* **2021**, *11*, 38–49.
39. Kermanshachi, S.; Safapour, E. Identification and quantification of project complexity from perspective of primary stakeholders in US construction projects. *J. Civ. Eng. Manag.* **2019**, *25*, 380–398. [CrossRef]
40. Bilgin, G.; Erol, H.; Atasoy, G.; Dikmen, I.; Birgonul, M.T. Exploring pattern of complexity in mega construction projects. *Int. J. Manag. Proj. Bus.* **2022**, *15*, 1064–1090. [CrossRef]
41. Banaszak, J.; Palter, R.; Parsons, M. *Stopping the Insanity: Three Ways to Improve Contractor-Owner Relationships on Capital Projects*; McKinsey & Company: New York, NY, USA, 2017.
42. Yoshikuni, A.C.; Dwivedi, R. The role of enterprise information systems strategies enabled strategy-making on organizational innovativeness: A resource orchestration perspective. *J. Enterp. Inf. Manag.* **2023**, *36*, 172–196. [CrossRef]
43. Peurifoy, R.L.; Schexnayder, C.J.; Schmitt, R.L.; Shapira, A. *Construction Planning, Equipment, and Methods*; McGraw-Hill Education: New York, NY, USA, 2018.
44. Zwikael, O. Critical planning processes in construction projects. *Constr. Innov.* **2009**, *9*, 372–387. [CrossRef]
45. Hamzeh, F.R.; El Samad, G.; Emdanat, S. Advanced metrics for construction planning. *J. Constr. Eng. Manag.* **2019**, *145*, 04019063. [CrossRef]
46. Gidado, K. Project complexity: The focal point of construction production planning. *Constr. Manag. Econ.* **1996**, *14*, 213–225. [CrossRef]
47. Koskela, L.; Howell, G. (Eds.) Reforming Project Management: The Role of Planning, Execution and Controlling. In Proceedings of the 9th International Group for Lean Construction Conference, Gramado, Brazil, 6–8 August 2002.
48. El-sabek, L.M. Framework for Managing Integration Challenges of Production Planning and Control in International Construction Mega-Projects. Ph.D. Thesis, University of Toronto, Toronto, ON, Canada, 2017.
49. Faniran, O.O.; Oluwoye, J.O.; Lenard, D.J. Interactions between construction planning and influence factors. *J. Constr. Eng. Manag.* **1998**, *124*, 245–256. [CrossRef]

50. Shehu, Z.; Akintoye, A. The critical success factors for effective programme management: A pragmatic approach. *Built Hum. Environ. Rev.* **2009**, *2*, 1–24.
51. Baldwin, A.; Bordoli, D. *Handbook for Construction Planning and Scheduling*; John Wiley & Sons: Hoboken, NJ, USA, 2014.
52. Chapman, R.J. A framework for examining the dimensions and characteristics of complexity inherent within rail megaprojects. *Int. J. Proj. Manag.* **2016**, *34*, 937–956. [CrossRef]
53. Martins, S.S.; Evangelista, A.C.J.; Hammad, A.W.; Tam, V.W.; Haddad, A. Evaluation of 4D BIM tools applicability in construction planning efficiency. *Int. J. Constr. Manag.* **2020**, *22*, 2987–3000. [CrossRef]
54. Lock, D. *The Essentials of Project Management*; Routledge: Milton Park, UK, 2020.
55. Sadeh, H.; Mirarchi, C.; Pavan, A. Technological transformation of the construction sector: A conceptual approach. *Int. J. Constr. Manag.* **2021**, *23*, 1704–1714. [CrossRef]
56. Amer, F.; Koh, H.Y.; Golparvar-Fard, M. Automated methods and systems for construction planning and scheduling: Critical review of three decades of research. *J. Constr. Eng. Manag.* **2021**, *147*, 03121002. [CrossRef]
57. Wang, X.; Love, P.E.D.; Kim, M.J.; Park, C.-S.; Sing, C.-P.; Hou, L. A conceptual framework for integrating building information modeling with augmented reality. *Autom. Constr.* **2013**, *34*, 37–44. [CrossRef]
58. AlSaggaf, A.; Jrade, A. ArcSPAT: An integrated building information modeling (BIM) and geographic information system (GIS) model for site layout planning. *Int. J. Constr. Manag.* **2021**, *23*, 1–25. [CrossRef]
59. Petroutsatou, K.; Apostolidis, N.; Zarkada, A.; Ntokou, A. Dynamic planning of construction site for linear projects. *Infrastructures* **2021**, *6*, 21. [CrossRef]
60. Kim, J.; Chi, S. Multi-camera vision-based productivity monitoring of earthmoving operations. *Autom. Constr.* **2020**, *112*, 103121. [CrossRef]
61. Irizarry, J.; Karan, E.P.; Jalaei, F. Integrating BIM and GIS to improve the visual monitoring of construction supply chain management. *Autom. Constr.* **2013**, *31*, 241–254. [CrossRef]
62. Guo, F.; Jahren, C.T.; Hao, J.; Zhang, C. Implementation of CIM-related technologies within transportation projects. *Int. J. Constr. Manag.* **2020**, *20*, 510–519. [CrossRef]
63. Abdullahi, I.; Kapogiannis, G.; Lemanski, M.K.; Jimenez-Bescos, C. Developing Competent Project Managers for Mega Infrastructure Construction: A Digital Construction Approach. In Proceedings of the European Conference on Computing in Construction, Athens, Greece, 19–28 July 2021.
64. Liu, Z.; Lu, Y.; Nath, T.; Wang, Q.; Tiong, R.L.K.; Peh, L.L.C. Critical success factors for BIM adoption during construction phase: A Singapore case study. *Eng. Constr. Archit. Manag.* **2022**, *29*, 3267–3287. [CrossRef]
65. Hwang, B.-G.; Zhao, X.; Yang, K.W. Effect of BIM on rework in construction projects in Singapore: Status quo, magnitude, impact, and strategies. *J. Constr. Eng. Manag.* **2019**, *145*, 04018125. [CrossRef]
66. Duong, C.D.; Wach, K.; Vu, N.X.; Ha, S.T.; Nguyen, B.N. Entrepreneurial education, government policies and programmes, and entrepreneurial behaviour: A serial moderated mediation model. *Entrep. Bus. Econ. Rev.* **2022**, *10*, 37–54. [CrossRef]
67. Matthews, A.; Ta, B. (Eds.) Applying a National BIM Model to Vietnam's National Implementation of BIM: Lessons Learned from the UK-Vietnam Collaboration for the Industry. In Proceedings of the CIGOS 2019, Innovation for Sustainable Infrastructure: Proceedings of the 5th International Conference on Geotechnics, Civil Engineering Works and Structures, Hanoi, Vietnam, 31 October–1 November 2019; Springer: Berlin/Heidelberg, Germany, 2020.
68. Creswell, J.W.; Creswell, J.D. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*; Sage Publications: Newbury Park, CA, USA, 2017.
69. Pollack, J. The changing paradigms of project management. *Int. J. Proj. Manag.* **2007**, *25*, 266–274. [CrossRef]
70. Hill, R. What sample size is "enough" in internet survey research. *Interpers. Comput. Technol. Electron. J. 21st Century* **1998**, *6*, 1–12.
71. Lemański, M.K. Reverse Transfer of HRM Practices from Emerging Market Subsidiaries: Organizational and Country-Level Influences, Multinational Enterprises, Markets and Institutional Diversity. *Prog. Int. Bus. Res.* **2014**, *9*, 399–415. [CrossRef]
72. Sharma, G. Pros and cons of different sampling techniques. *Int. J. Appl. Res.* **2017**, *3*, 749–752.
73. Medway, R.L.; Fulton, J. When more gets you less: A meta-analysis of the effect of concurrent web options on mail survey response rates. *Public Opin. Q.* **2012**, *76*, 733–746. [CrossRef]
74. Bosch-Rekveldt, M.; Jongkind, Y.; Mooi, H.; Bakker, H.; Verbraeck, A. Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. *Int. J. Proj. Manag.* **2011**, *29*, 728–739. [CrossRef]
75. Ahn, S.; Shokri, S.; Lee, S.; Haas, C.T.; Haas, R.C. Exploratory study on the effectiveness of interface-management practices in dealing with project complexity in large-scale engineering and construction projects. *J. Manag. Eng.* **2017**, *33*, 04016039. [CrossRef]
76. Fellows, R.F.; Liu, A.M. *Research Methods for Construction*; John Wiley & Sons: Hoboken, NJ, USA, 2015.
77. McMillan, J.H.; Schumacher, S. *Research in Education: Evidence-Based Inquiry*; MyEducationLab Series; Pearson: London, UK, 2010.
78. Rochon, J.; Kieser, M. A closer look at the effect of preliminary goodness-of-fit testing for normality for the one-sample t-test. *Br. J. Math. Stat. Psychol.* **2011**, *64*, 410–426. [CrossRef] [PubMed]
79. Rea, L.M.; Parker, R.A. *Designing and Conducting Survey Research: A Comprehensive Guide*; John Wiley & Sons: Hoboken, NJ, USA, 2014.
80. Kunz, J.; Fischer, M. Virtual design and construction. *Constr. Manag. Econ.* **2020**, *38*, 355–363. [CrossRef]
81. Pellerin, R.; Perrier, N. A review of methods, techniques and tools for project planning and control. *Int. J. Prod. Res.* **2019**, *57*, 2160–2178. [CrossRef]

82. Rashidi, A.; Yong, W.Y.; Maxwell, D.; Fang, Y. Construction planning through 4D BIM-based virtual reality for light steel framing building projects. *Smart Sustain. Built Environ.* **2022**. *ahead of print*. [CrossRef]
83. Wang, Z.; Wang, T.; Hu, H.; Gong, J.; Ren, X.; Xiao, Q. Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Autom. Constr.* **2020**, *111*, 103063. [CrossRef]
84. Sharma, S.; Bansal, V. Location-based planning and scheduling of highway construction projects in hilly terrain using GIS. *Can. J. Civ. Eng.* **2018**, *45*, 570–582. [CrossRef]
85. Russell, R.S.; Taylor, B.W. *Operations and Supply Chain Management*; John Wiley & Sons: Hoboken, NJ, USA, 2019.
86. Vrijhoef, R.; Koskela, L. The four roles of supply chain management in construction. *Eur. J. Purch. Supply Manag.* **2000**, *6*, 169–178. [CrossRef]
87. Vrijhoef, R. *Supply Chain Integration in the Building Industry: The Emergence of Integrated and Repetitive Strategies in a Fragmented and Project-Driven Industry*; Ios Press: Amsterdam, The Netherlands, 2011.
88. Magill, L.J.; Jafarifar, N.; Watson, A.; Omotayo, T. 4D BIM integrated construction supply chain logistics to optimise on-site production. *Int. J. Constr. Manag.* **2020**, *22*, 2325–2334. [CrossRef]
89. Watters, C. When Criminals Abuse the Blockchain: Establishing Personal Jurisdiction in a Decentralised Environment. *Laws* **2023**, *12*, 33. [CrossRef]
90. Chang, S.E.; Chen, Y. When blockchain meets supply chain: A systematic literature review on current development and potential applications. *IEEE Access* **2020**, *8*, 62478–62494. [CrossRef]
91. Queiroz, M.M.; Telles, R.; Bonilla, S.H. Blockchain and supply chain management integration: A systematic review of the literature. *Supply Chain. Manag. Int. J.* **2020**, *25*, 241–254. [CrossRef]
92. Liang, Y.; Watters, C.; Lemański, M.K. Responsible Management in the Hotel Industry: An Integrative Review and Future Research Directions. *Sustainability* **2022**, *14*, 17050. [CrossRef]
93. Ivić, I.; Cerić, A. Risks Caused by Information Asymmetry in Construction Projects: A Systematic Literature Review. *Sustainability* **2023**, *15*, 9979. [CrossRef]
94. Ganah, A.; Lea, G. A global analysis of BIM standards across the globe: A critical review. *J. Proj. Manag. Pract. (JPMP)* **2021**, *1*, 52–60. [CrossRef]
95. Kenneth-Southworth, E.; Watters, C.; Gu, C. Entrepreneurship in China: A review of the role of normative documents in China's legal framework for encouraging entrepreneurship. *Entrep. Bus. Econ. Rev.* **2018**, *6*, 71. [CrossRef]
96. Watters, C.G.; Feng, X.; Tang, Z. China overhauls work permit system for foreigners. *Ind. Law J.* **2018**, *47*, 263–277. [CrossRef]
97. Sabatini, A.; Cucculelli, M.; Gregori, G.L. Business model innovation and digital technology: The perspective of incumbent Italian small and medium-sized firms. *Entrep. Bus. Econ. Rev.* **2022**, *10*, 23–35. [CrossRef]