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Effect of Digital Innovations on the Success of Construction Projects: A Case of Rusizi Port Construction Project

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Abstract: *Despite increasing digitalization, construction projects continue to experience delays, cost overruns, poor coordination, and quality deficiencies. This study assessed the effect of digital innovations on the success of the Rusizi Port Construction Project in Rwanda. The specific objectives examined Building Information Modeling (BIM), Digital Project Management Systems, and Digital Collaboration and Communication Tools in relation to reduced rework and errors, transparency and accountability, and coordination and teamwork, respectively. Resource-Based Theory, Systems Theory, Principal-Agent Theory, and Stakeholder Theory guided the study. A descriptive survey design was adopted, and a census of 56 project personnel and beneficiaries was used. Questionnaires supplied the data, which were analysed through descriptive statistics, Pearson correlation, and multiple regression. Digital innovations were positively associated with project success ($r = 0.890$, $p < 0.001$). The reported model summary gave $R = 0.947$ and $R^2 = 0.897$. BIM ($B = 0.750$, $p < 0.001$), Digital Project Management Systems ($B = 1.250$, $p < 0.001$), and Digital Collaboration and Communication Tools ($B = 0.500$, $p = 0.005$) were positive predictors in the reported coefficients table. Respondents also identified weaknesses in information updates and equal participation. The study recommended strengthening BIM training, data governance, and inclusive digital collaboration.*

Keywords: *Digital innovations, Building Information Modeling, Digital project management systems, Digital collaboration, Construction project success*

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1. Introduction

Digital innovations increasingly shape construction planning, project control, information exchange, and stakeholder coordination. Digital tools such as Building Information Modeling, cloud-based platforms, and project management systems offer opportunities to improve communication, productivity, and quality during project implementation (Brozovsky et al., 2024; Nguyen & Adhikari, 2023). Their use is relevant across pre-construction, construction, and facility-management activities.

Nevertheless, the construction sector continues to experience delays, budget overruns, weak coordination, and quality deficiencies. The source dissertation identifies the persistence of these difficulties even as digital technologies become more accessible (Nozari et al., 2026). These issues create uncertainty about whether digital adoption consistently delivers the expected project outcomes.

For the Rusizi Port Construction Project, the study examined the ways BIM, Digital Project Management Systems, and Digital Collaboration and Communication Tools related to three aspects of project success: reduced rework and errors, transparency and accountability, and improved coordination and teamwork. The research

addressed a contextual gap because the reviewed studies had not established these relationships within the selected Rwandan construction project.

1.1 General Objective

The general objective was to assess the effect of digital innovations on the success of construction projects, using the Rusizi Port Construction Project as a case study.

1.2 Specific Objectives

The study addressed three specific objectives aligned with the digital innovations examined.

1. To investigate the influence of Building Information Modeling on reduced rework and errors at the Rusizi Port Construction Project.
2. To examine the contribution of Digital Project Management Systems to transparency and accountability at the Rusizi Port Construction Project.
3. To analyse the relationship between Digital Collaboration and Communication Tools and improved coordination and teamwork at the Rusizi Port Construction Project.

2. Literature Review

This section presents the theoretical and empirical reviews reported in the full dissertation. It retains the four theories and all four substantive empirical-review subsections, with only grammatical and citation-format corrections.

2.1 Theoretical Review

The theoretical review brings together perspectives on resource capability, interdependent project systems, principal-agent accountability, and stakeholder participation in digital innovation adoption.

2.1.1 Resource-Based Theory

In the world economy, all firms are looking to cost-down and provide real-time delivery. The resource-based view of the firm (RBV) combines two perspectives: internal analysis of phenomena within a company, and external analysis of the industry and its competitive environment. Specifically, the RBV considers the firm as a bundle of resources: tangible resources, intangible resources, and organizational capabilities. Competitive advantages that are sustainable over time generally arise from the creation of bundles of resources and capabilities. For advantages to be sustainable, four criteria must be satisfied: rarity, value, difficulty of imitation, and difficulty of substitution. Such an evaluation requires sound knowledge of the competitive context in which the firm exists (Wernerfelt, 1984). The resource-based view is an important element of organizational analysis.

Wernerfelt (1984) argues that it is possible to find the optimal product-market activities by specifying a resource profile for a firm. According to the resource-based view, supply chain as used here denotes the channel of firms and intermediaries through which a product moves from the original sources of its basic raw materials through conversion/manufacture and then distribution in its finished form to the ultimate consumers. Hence a given firm must result in a resource-based value before considering other actions as managers understand that all the suppliers should react to the changes from the supply chain. The supply chain is compressed to be very flexible to changes from the market (Wernerfelt, 1984).

In this study, digital innovations represent valuable technological resources that enable construction firms to improve project planning, coordination, communication, monitoring, and decision-making. The theory suggests that construction projects that effectively leverage these digital resources are more likely to achieve success through improved cost efficiency, timely completion, quality performance, and stakeholder satisfaction. Therefore, RBT provides a foundation for understanding how digital innovations contribute to construction project success by creating competitive advantages and enhancing organizational performance.

2.1.2 Systems Theory

Systems theory is the interdisciplinary study of systems in general, with the goal of elucidating principles that can be applied to all types of systems at all nesting levels in all fields of research (Scott & Davis, 2007). The term does not yet have a well-established, precise meaning, but systems theory can reasonably be considered a specialization of systems thinking; alternatively, as a goal output of systems science, with an emphasis on generality useful across a broad range of systems (versus the particular models of individual fields). The systems view was based on several fundamental ideas (Scott & Davis, 2007). First, all phenomena can be viewed as a web of relationships among elements, or a system. Second, all systems, whether electrical, biological, or social, have common patterns, behaviors, and properties that the observer can analyze and use to develop greater insight into the behavior of complex phenomena and to move closer toward a unity of the sciences (Scott & Davis, 2007).

A system in this frame of reference can contain regularly interacting or interrelating groups of activities. In supply chain management, the context System Theory brings together various components of a complex supply chain; that is the human, capital, information, materials and financial resources to form a subsystem which is then

part of a larger system of supply chains or network. The theory argues that for a holistic perspective ST must be employed to understand the internal and external factors that shape an organization's supply chain performance (Scott & Davis, 2007).

Public organizations are open systems that receive inputs (demands, support, etc.) from their environment which are being absorbed and manufactured (throughput) through policy processes and the use of management techniques which leads to outcomes that generate new feedback from the organizational external environment (Scott & Davis, 2007). Using this theory implies an analysis of how the external environment of organizations influences them to implement changes with regard to the integration of their services. By doing so, open systems theory leads to the insight of contingency or the fact that each public organization works within its own societal environment which is partly identical and partly different or specific.

Assessing both the internal and external situational factors becomes necessary in order to understand why each organization has a certain specific character (Scott & Davis, 2007). Following the structural contingency theory, this specific character refers to the optimal structure which is different for each organization. Such a perspective emphasizes effectiveness and efficiency.

Organizational reforms need to be considered as efforts to achieve the best fit between organizational structures and the environment surrounding an organization. Contingency theory assumes a rational adaptation to the environment (Scott & Davis, 2007).

Open systems theory stresses the cohesion of a system or organization and considers the behavior of an organization as a whole without looking at the behavior of organizational groups or individuals (Scott & Davis, 2007). In Open System Theory, each system and its subsystems adapt to internal and external demands and feedback. Demands external to the public sector procurement encompass environmental factors such as suppliers, legislation, and technological advancement among other factors. Organizations continuously adapt system functioning in response to feedback and informational signals to counteract entropy. For example, aligning organizational policies to meet performance targets set by external agencies exemplifies the dynamic interaction between the organization and its external environment (Scott & Davis, 2007).

Digital innovations facilitate integration and coordination among different project components by enabling real-time communication, data sharing, and information management. Technologies such as BIM and IoT enhance collaboration among architects, engineers, contractors, suppliers, and clients, thereby improving project efficiency and reducing errors. Systems Theory explains how digital innovations improve interactions among different project elements, leading to better coordination, enhanced project control, and improved project success.

2.1.3 Principal-Agent Theory

Based on the separation of ownership and control of economic activities between the agent and the principal, various agency problems may arise, such as asymmetric information between the principal and the agent, conflicting objectives, differences in risk aversion, outcome uncertainty, behavior based on self-interest, and bounded rationality (Baiman & Rajan, 2002).

The contract between the principal and the agent governs the relationship between the two parties, and the aim of the theory is to design a contract that can mitigate potential agency problems (Baiman & Rajan, 2002). According to the theory, the "most efficient contract" includes the right mix of behavioral and outcome-based incentives to motivate the agent to act in the interests of the principal (Eisenhardt, 1989). The alignment of incentives is an important issue in SCM. Misalignment often stems from hidden actions or hidden information. However, by creating contracts with supply chain partners that balance rewards and penalties, misalignment can be mitigated (Eisenhardt, 1989).

A major challenge in principal-agent relationships is information asymmetry, where agents may possess more information than principals, leading to monitoring difficulties, inefficiencies, and project risks. Digital innovations help reduce these challenges by increasing transparency, providing real-time project information, enabling performance monitoring, and facilitating accountability. Principal-Agent Theory explains how digital innovations reduce information asymmetry and improve accountability, thereby enhancing construction project success.

2.1.4 Stakeholder Theory

The origins of stakeholder theory draw on four key academic fields: sociology, economics, politics and ethics and especially the literature on corporate planning, systems theory, corporate social responsibility and organizational theory (Freeman, 1984). Freeman over the course of his work entitled Strategic Management: A Stakeholder Approach, widely regarded as a foundational contribution to stakeholder theory, defines how stakeholders with similar interests or rights form groups (Freeman, 1984). What Freeman was seeking to explain was the relationship between the company and its external environment and its behavior within this environment. The author set out his model as if a chart in which the company is positioned at the center and is involved with stakeholders connected with the company. In this model, the company-stakeholder relationships are dyadic and mutually independent (Bryson, 2004).

According to Freeman (1984), the basic premises of Stakeholder theory are: the organization enters into relationships with many groups that influence or are influenced by the company`s stakeholders in accordance with Freeman's terminology; the theory focuses on the nature of these relationships in terms of processes and results for the company and for stakeholders, the interests of all legitimate stakeholders are of intrinsic value and it is assumed that there is no single prevailing set of interests.

The theory focuses on management decision-making and explains how stakeholders try and influence organizational decision-making processes so as to be consistent with their needs and priorities. In terms of organizations, these should attempt to understand and balance the interests of the various participants. Taking these premises into consideration and according to Bryson (2004), the concept of stakeholder management was developed so that organizations could recognize, analyze and examine the characteristics of partners being influenced by organizational behavior. Thus, management is carried out over three levels: the identification of stakeholders, the development of processes identifying and interpreting their needs and interests and the construction of relationships with the entire process structured around the organization's respective objectives.

Digital innovations improve stakeholder engagement through enhanced communication, information sharing, collaboration, and transparency. Technologies such as BIM platforms and cloud-based collaboration tools enable stakeholders to access project information, participate in decision-making, and coordinate activities more effectively. As stakeholder satisfaction is a key indicator of project success, the use of digital innovations can contribute significantly to achieving stakeholder expectations and project objectives.

Stakeholder Theory explains how digital innovations facilitate collaboration and communication among project stakeholders, thereby contributing to successful project outcomes.

2.2 Empirical Review

Construction projects digitalization refers to integrating and utilizing digital technologies and systems in port operations to enhance efficiency, productivity, and sustainability. Scholars have emphasized the multi-dimensional nature of port digitalization, encompassing various aspects such as automation, data analytics, Internet of Things (IoT) integration, and advanced communication systems (Belmoukari et al., 2023; Li et al., 2023). Belmoukari et al. (2023) highlight the importance of digital platforms facilitating information sharing and collaboration among stakeholders in port ecosystems. Numerous studies have investigated the impact of port digitalization on various performance indicators.

The construction project's digitalization offers numerous benefits that can improve operational efficiency, reduce costs, enhance transparency, and increase customer satisfaction (Almeida, 2023; Li et al., 2023) and highlight that digitalization enables real-time data sharing, facilitating more accurate planning and resource allocation. However, challenges accompany the implementation of construction digitalization. These challenges include the need for significant infrastructure investments, concerns regarding cybersecurity, and addressing workforce skill gaps (Almeida, 2023). Infrastructure requirements such as installing sensor networks and advanced communication systems are crucial for effective data collection and analysis (Li et al., 2023).

Additionally, cybersecurity measures must be in place to protect sensitive data and ensure the smooth functioning of digital systems. The correlation between port digitalization and cybersecurity is evident in the increased efficiency and vulnerability that digital transformation brings. While digitalization offers numerous benefits for port operations, it also necessitates robust cybersecurity measures to protect against evolving threats (Almeida, 2023). Ports must adopt a holistic approach to cybersecurity, integrating advanced technologies, compliance with regulations, and proactive risk management strategies to ensure secure and resilient operations (Almeida, 2023).

The advancement of globalization, economic development, and technological progress have contributed to the growth of international trade, with approximately 90% of global trade being carried by sea (Belmoukari et al., 2023). Facing increasing complexity of trade, as well as unexpected events such as natural disasters and pandemics, ports need to offer diversified, efficient, cost-effective, and flexible services to meet customer demands and expectations. To this end, ports urgently need digital transformation.

Digital transformation is commonly identified as the implementation of digital technologies in construction, involving artificial intelligence, 5G, big data, the Internet, and blockchain to automate port operations and enable intelligent decision making (Li et al., 2023). It plays a crucial role in enhancing operational efficiency, reducing operational costs (Zhang et al., 2024), and enabling adaptability to dynamic environments (Almeida, 2023). The use of digital technology can effectively enhance operational efficiency through improved information transmission and accurate information verification (Li et al., 2023; Belmoukari et al., 2023). There is also a positive relationship between network effects and digital technologies, which can enhance port resilience through the coordination of

human resources, information, and various technologies (Li *et al.*, 2023).

This discrepancy underscores a pivotal challenge: the delicate equilibrium between digital investments and their resultant benefits. Ports are required to make significant investments (Almeida, 2023), encompassing both the development and deployment of digital technologies and the construction of associated infrastructure. However, forecasting the benefits of these digital transformations poses a considerable challenge. The digital research and development (R&D) efficiency is significantly dependent on the capabilities of technology companies, upon which ports rely for essential data to facilitate informed decision-making processes (Almeida, 2023). In reality, ports are under incomplete information, which introduces uncertainties about the benefits of digital transformation and influences decision-making processes. Furthermore, there exists a risk of technology companies overstating R&D efficiency, which can lead to substantial unilateral losses for ports (Almeida, 2023). Consequently, many ports may adopt a cautious and conservative attitude about digital investment (Li et al., 2023).

3. Methodology

This section describes the procedures applied to the research design, population, instruments, pilot assessment, data analysis, and ethical safeguards.

3.1 Research Design

A descriptive survey research design was adopted to examine the perceived contribution of digital innovations to the Rusizi Port Construction Project. The study used questionnaire responses to describe the three innovation dimensions and examine their relationships with project success. The correlational and regression analyses assessed statistical associations; they did not establish causal effects.

3.2 Target Population and Sampling

The target population consisted of 56 respondents from the project officer, beneficiary, subcontractor, finance and accounting, procurement and logistics, and administration categories. A census, also described in the dissertation as universal sampling, was adopted because the target population was relatively small.

3.3 Data Collection Instruments

The study administered structured and open-ended questionnaires using a drop-and-collect approach. The questionnaire was organized around Building Information Modeling, Digital Project Management Systems, and Digital Collaboration and Communication Tools, together with related project-success outcomes.

3.4 Pilot Study, Validity and Reliability

The questionnaire was reviewed for content and face validity by the supervisor, and a pilot study was described as involving 10% of the target population.

Table 1. Original Reliability Statistics

Cronbach's Alpha	N of Items
.981	10

The study reported test–retest procedures and Cronbach's alpha for internal consistency. It presented an overall Cronbach's alpha of 0.981 across 10 items. No numerical Content Validity Index was provided in the source.

3.5 Data Analysis

Questionnaire data were checked, coded, and analysed using SPSS. Percentages, means, and standard deviations summarized responses. Pearson correlation was used to evaluate bivariate association, while a multiple regression model assessed the contributions of BIM, project management systems, and digital collaboration tools to reported project success. Open-ended responses were intended for thematic categorization.

3.6 Ethical Considerations

The researcher sought permission from the University of Kigali and the Rusizi Port project administration. Respondents were informed that their participation was for academic purposes, and the study emphasized confidentiality, privacy, anonymity, and voluntary participation.

4. Results and Discussions

This section presents the response information and inferential findings, followed by objective-based

discussions. The original tables have been reproduced without altering their structure, formatting, wording, or statistical values.

4.1 Response Rate

The study targeted 56 individuals through census sampling and presented questionnaire-based results for 56 respondents. It did not include a separate questionnaire return-rate table. Therefore, no additional response-rate statistic was invented for this manuscript.

4.2 Correlation Analysis

Pearson correlation assessed the relationship between digital innovations and the success of construction projects.

Table 2. Correlations

		Digital Innovations	Success of construction projects
Digital Innovations	Pearson Correlation	1	. 890**
	Sig. (2-tailed)		.000
	N	**56**	**56**
Success of construction projects	Pearson Correlation	.890**	1
	Sig. (2-tailed)	.000	
	N	**56**	**56**

**. Correlation is significant at the 0.01 level (2-tailed).

The reported result indicated a strong positive association; however, it did not establish causation. The correlation between digital innovations and project success was r = 0.890 (reported p = .000, conventionally p < .001), based on N = 56 respondents.

4.3 Regression Analysis

The dissertation reported a multiple regression model for the combined predictors. Its model summary, ANOVA, and regression coefficients are reproduced below exactly as given in the original tables.

Table 3. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.947[a]	.897	.872	.144

a. Predictors: (Constant), Building Information Modeling, Digital Project Management Systems, and Digital Collaboration & Communication Tools

The model summary reported R = 0.947, R^2 = 0.897, adjusted R^2 = 0.872, and a standard error of 0.144. Accordingly, the table attributed 89.7% of the observed variance in project-success scores to the predictors within the fitted model, subject to the diagnostic limitation noted above.

Table 4. ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	2.188	3	.729	34.714	.000[a]
	Residual	.250	110	.021		
	Total	2.438	103			

a. Predictors: (Constant), Building Information Modeling, Digital Project Management Systems, and Digital Collaboration & Communication Tools

b. Dependent Variable: Success of construction projects

ANOVA table reported F = 34.714 and Sig. = .000. However, its displayed residual and total degrees of freedom do not reconcile with one another or with the 56-person dataset. The table remains unchanged, and the statistical test should not be treated as independently verified.

Table 5. Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.500	.191		2.619	.022
	Building Information Modelling	.750	.132	.635	5.692	.000
	Digital Project Management Systems	1.250	.132	1.059	9.487	.000
	Digital Collaboration & Communication Tools	.500	.144	.424	3.464	.005

a. Dependent Variable: Success of construction projects

The reported unstandardized coefficients were positive for BIM (B = 0.750, p < 0.001), Digital Project Management Systems (B = 1.250, p < 0.001), and Digital Collaboration and Communication Tools (B = 0.500, p = 0.005). These coefficients describe estimated changes in the dependent-variable scale for one-unit changes in predictors, holding the other predictors constant; they must not be interpreted as percentage increases.

The reported regression equation was $Y = 0.500 + 0.750X_1 + 1.250X_2 + 0.500X_3 + \varepsilon$, where X_1 represents BIM, X_2 represents Digital Project Management Systems, and X_3 represents Digital Collaboration and Communication Tools.

4.4 Discussion of Findings

The discussion follows the three study objectives, preserving the original descriptive-result tables while relating the findings to the theories and empirical literature discussed in previous section.

4.4.1 Building Information Modeling and Reduced Rework and Errors

Respondents strongly endorsed the role of BIM in detecting design conflicts, coordinating construction documentation, supporting prefabrication, and reducing rework. The high item means indicated strong agreement, not independent evidence that the stated reductions in construction costs or error rates were realized. Resource-Based Theory suggests that BIM can function as a valuable organizational capability when project teams have the skills to use it effectively. The reviewed work on digitalization similarly emphasizes information sharing, coordination, and operational efficiencies (Belmoukari et al., 2023).

4.4.2 Digital Project Management Systems and Transparency and Accountability

Respondents rated document access, workflow visibility, task responsibilities, and issue tracking favourably. They rated timely, accurate, and regularly updated information more cautiously. Systems Theory explains how coordinated information flows connect participants, resources, decisions, and project activities. The empirical review similarly identifies real-time data sharing and governance as important aspects of effective digitalization (Almeida, 2023; Li et al., 2023).

4.4.3 Digital Collaboration and Communication Tools, Coordination, and Teamwork

Respondents generally rated productivity, flexible communication, shared information, and decision-making positively. However, equal participation and transparent communication received a comparatively low mean. Stakeholder Theory connects these findings to the importance of including relevant participants, while Diffusion of Innovation (Rogers, 2003) highlights differences in readiness and participation across users. The original empirical review further identifies organizational culture and the role of communication channels in technology adoption (Belmoukari et al., 2023; Almeida, 2023).

5. Conclusions and Recommendations

This section draws conclusions from the three specific objectives and presents recommendations for improving digital innovation practices at the Rusizi Port Construction Project. The recommendations address the observed strengths and weaknesses while recognizing the limits of the reported statistical analysis.

5.1 Conclusions

The study concluded that BIM, Digital Project Management Systems, and Digital Collaboration and Communication Tools were positively associated with construction project success at Rusizi Port. BIM supported perceived improvements in design coordination and reduction of rework; project management systems supported accountability and workflow visibility; and collaboration tools improved information exchange and teamwork. However, challenges remained in maintaining timely and accurate data and ensuring equal participation in digital communication. Because the research used a descriptive, correlational design and the original ANOVA table contained inconsistent degrees of freedom, the results should not be interpreted as conclusive causal evidence.

5.2 Recommendations

The recommendations respond to the three study objectives and focus on the implementation conditions needed for effective digital innovation use.

1. Project managers should institutionalize BIM across the design, planning, construction, and maintenance phases and provide regular training in clash detection, 3D modelling, and coordinated design review.
2. Project teams should strengthen digital project management data governance by verifying information, assigning responsibility for timely updates, and monitoring the quality and completeness of records, workflows, and issue logs.
3. Project leaders should establish inclusive digital communication procedures, support staff with different levels of digital readiness, and use structured feedback mechanisms to encourage participation in project decisions.

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