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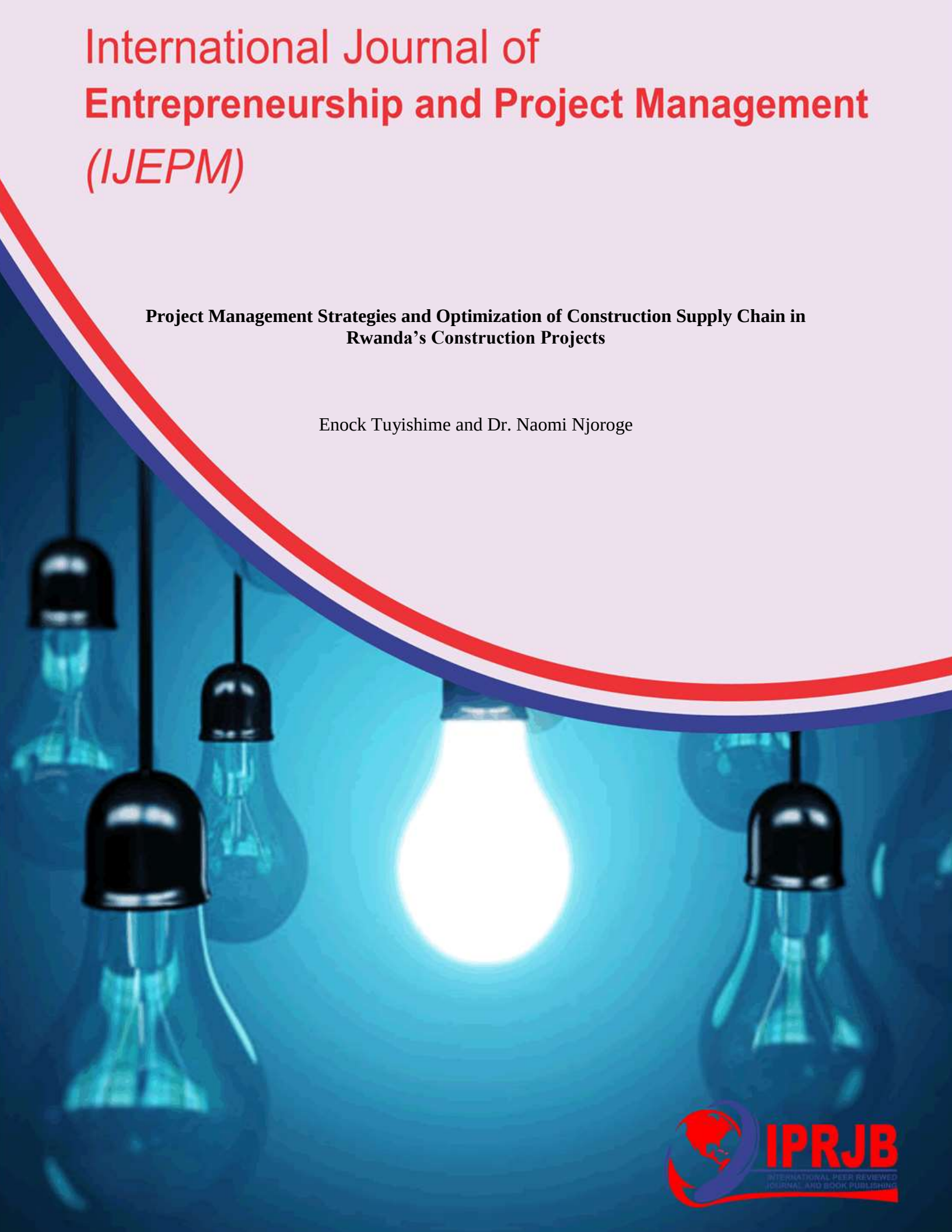

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Abstract

Purpose: This study explored management strategies and their influence on optimizing the construction supply chain in Rwanda, focusing on the Amahoro Stadium project. The specific objectives included assessing the impact of logistics management, technology integration.

Methodology: A mixed-methods approach with a descriptive survey design was used, targeting 128 individuals and entities involved in the construction supply chain of Amahoro Stadium. The sample size of 97 respondents was determined using the Granular formula. Data were collected through questionnaires and interviews, combining both quantitative and qualitative insights.

Findings: The study revealed that logistics management, technology integration, and customer management all have significant positive relationships with the optimization of the construction supply chain in Rwanda. Key findings included a strong agreement among respondents that effective transportation (43.2%), inventory control (48.4%), and customer feedback (83.6%) influence supply chain optimization. The correlation analysis showed that 87.6% of the variation in construction supply chain optimization can be explained by these three independent variables. The study concluded that a comprehensive strategy involving logistics management, technology integration, and customer engagement is essential for optimizing construction supply chains in Rwanda.

Unique Contribution to Theory, Practice and Policy: Recommendations include investing in logistics training, adopting advanced technologies, and fostering customer relationships to improve satisfaction and project outcomes. Further research into the long-term impacts of these strategies on supply chain optimization and sustainability was also suggested.

Keywords: *Project Management Strategies, Optimization, Construction Supply Chain, Rwanda*

JEL Codes of Classification: *L74, C61, L92, O55*

INTRODUCTION

The construction industry contributes significantly to GDP globally, particularly in developing countries where it accounts for 6% to 9% (Lopes, 2017). Urbanization trends, such as those observed in Vienna with a projected 22% population growth by 2050, highlight the demand for sustainable urban planning. Similarly, in the Netherlands, changes in construction practices reflect a shift in stakeholder roles, with suppliers and subcontractors now representing a significant share of the sector's turnover. In South Africa, the construction industry is a major economic contributor, adding 4% to GDP and employing over 1.3 million people. Despite its importance, the industry faces challenges such as inefficiencies in supply chain management (SCM) and limited stakeholder collaboration.

These global trends resonate with challenges in Rwanda's construction sector, which is critical to the country's infrastructure development and economic growth. Like other nations, Rwanda grapples with fragmented networks, inefficiencies in logistics, and poor communication among stakeholders. For example, the Amahoro Stadium redevelopment project underscores the need for effective SCM practices to ensure timely delivery, cost efficiency, and sustainability. Drawing lessons from this project could guide the optimization of Rwanda's construction supply chain, addressing systemic issues and improving overall performance.

Focusing on supply chain integration, stakeholder collaboration, and sustainable practices offers significant potential to enhance Rwanda's construction sector. By addressing inefficiencies and leveraging innovative approaches, Rwanda can align its construction industry with national development goals, fostering economic growth and supporting urbanization efforts. The Amahoro Stadium case study provides a relevant framework for exploring these strategies in practice. This study examined strategies to handle obstacles and seize opportunities, ultimately assisting the project's successful completion and Rwanda's construction sector development. This study sought the following specific objectives: to assess the influence of logistics management on the optimization of the construction supply chain and to examine the extent to which the role of technology integration influenced the optimization of the construction supply chain.

Problem Statement

Rwanda’s construction sector faces significant supply chain challenges, particularly in large-scale projects like the Amahoro Stadium. For instance, during the stadium's redevelopment, delays in material deliveries and poor logistical planning led to missed project milestones, increased costs, and diminished project quality (Rwanda Development Board, 2021). Issues such as inconsistent material supply, limited coordination among stakeholders, and inadequate use of technology further compounded these problems, with logistical inefficiencies and infrastructure limitations playing a major role (World Bank, 2019). Despite previous attempts to address these challenges, the sector still struggles with integrating supply chain practices that could streamline operations and mitigate disruptions (KPMG, 2020). Research highlights that adopting advanced supply chain strategies, including technology-driven solutions and collaborative frameworks, can significantly enhance construction project performance (Zou et al., 2019).

Addressing these challenges in the Amahoro Stadium project offers a unique opportunity to not only improve project outcomes but also set a precedent for supply chain optimization across

Rwanda's construction industry. This could result in cost savings, timely project completion, and higher-quality infrastructure, contributing positively to the country's economic growth and development objectives.

Research Objectives

It was guided by the following specific objectives

i. To assess the influence of logistics management on optimization of construction supply chain.
ii. To examine the extent to which the role of technology integration influence optimization of construction supply chain.

LITERATURE REVIEW

Theoretical Review

Optimization of Construction Supply Chain

Previous studies support "supply chain integration" to become the key enabler that contributes to construction supply chain performance (Bankvall *et al*., 2010). Once conducted properly, supply chain integration can facilitate the full information sharing, and long-term trust among the SC actors (Meng et al., 2011), which in turn enhances material flows throughout the whole SC (Liu *et al*., 2017). In large CSC projects, to deal with the challenges of temporary and complex nature of the industry as well as increase the SC integration, construction firms have thought of TPL (Third-party logistics) providers to increase productivity at the construction site, reduce logistics costs and enhance the utilization of site assets (Rudberg, 2016). TPL partnership is based on the idea that a construction firm hires logistics professionals to manage all the logistics activities (transportation, material procurement, and storage). Using TPL, an interface is formalized to connect the SC network to the construction site (Le *et al*., 2018). Lack of SC integration also impacts the efficiency of site layout planning since the required data are reserved in many organizations as internal knowledge. Therefore, it is necessary to facilitate a platform that supports information sharing among the construction actors.

Technology Integration

The construction industry is more fragmented than industries like automotive or pharmaceuticals, where a few companies dominate the market. Due to the widespread locations of construction sites, the supply chain in this sector involves a diverse network of partners, including clients, contractors, house builders, designers, consultants, suppliers, installers, and end users. To optimize the construction supply chain, effective cross-enterprise coordination and strong business relationships are crucial among these organizations. As part of this process, organizations have shifted from a functional to a business process approach, capturing business processes in models and implementing them through enterprise applications such as ERP, EPP, EW, EQM, and SCM. A key trend in the industry is the inclusion of external entities clients, users, service providers, and suppliers into supply chain management. This integration requires seamless communication and information sharing across platforms, facilitated by evolving Internet applications such as portals and e-commerce. These systems, supported by the Internet infrastructure (telecommunications

companies, ISPs, and network equipment), link the various supply chain partners, enabling real-time collaboration and cost-effective integration over a global network.

Construction Supply Chain

The theoretical framework of the construction supply chain combines principles from supply chain management (SCM) and construction project management (CPM) to address the industry's unique challenges. SCM focuses on the efficient flow of materials, information, and finances across the network of organizations involved in delivering products and services (Mentzer et al., 2001), while in construction, it coordinates stakeholders such as suppliers, contractors, and clients to ensure timely delivery, cost minimization, and improved project performance (Koskela, 2000). Lean Construction, an adaptation of Lean manufacturing, plays a key role by reducing waste and enhancing workflow efficiency through techniques like Just-In-Time (JIT) delivery, Integrated Project Delivery (IPD), and the Last Planner System (LPS), which improve collaboration and predictability (Koskela, 1992). Additionally, the framework incorporates risk management and sustainability, essential for managing project complexity and mitigating disruptions (Ghadge et al., 2012). With increasing environmental awareness, sustainable practices, including eco-friendly materials and resource optimization, are integral to reducing the construction sector's environmental impact (Shen et al., 2007). This comprehensive approach ensures the efficient management of resources and processes, ultimately enhancing project outcomes.

Logistic Management

Logistics management is vital for operational efficiency and strategic success across industries, including construction, manufacturing, and retail. It involves planning, implementing, and controlling the flow of goods, services, and information to optimize supply chain processes, reduce costs, and enhance competitiveness. Scholars like Chopra and Meindl (2019) and Christopher (2016) highlight its role in coordinating transportation, inventory, and information flow, achieving operational excellence, and fostering competitive advantage. Advanced technologies such as RFID, GPS tracking, and automated systems have revolutionized logistics, enabling real-time visibility and predictive analytics. In construction, logistics management is crucial for ensuring timely delivery of materials and equipment, addressing challenges like complex supply chains and resource constraints (Seuring & Goldbach, 2016; Yu et al., 2020). By leveraging integrated supply chain strategies, collaboration, and technology, firms can enhance project efficiency, mitigate risks, and drive sustainable growth in a competitive market.

Empirical Review

Empirical studies have underscored the pivotal role of effective supply chain management strategies in optimizing construction projects. Segerstedt and Olofsson (2010) demonstrated in Sweden how Lean principles and Just-In-Time (JIT) delivery significantly reduced material waste and inventory costs, boosting site productivity. Similarly, Thunberg (2014) highlighted that supply chain integration, characterized by enhanced collaboration and information sharing among stakeholders, led to improved cost, time, and quality performance in construction projects. Studies in China (Wang, 2021) and Finland (Koskela, 2019) further corroborated these findings, emphasizing the benefits of well-organized logistics operations and centralized coordination in reducing project timelines and improving material flow.

Technological advancements such as BIM, RFID, IoT, and AI have also been shown to enhance supply chain efficiency. BIM fosters real-time collaboration and reduces errors (Lee et al., 2015), while RFID streamlines material tracking and inventory management (Lamban, 2017). IoT devices improve decision-making by providing real-time data (Li, 2019), and AI enhances predictive analytics for better project scheduling (Golizadeh, 2019). In Rwanda, studies by Mukarugwiza and Mbabazi (2019) and Nduhura et al. (2020) demonstrated that effective customer management, including structured feedback and early client involvement, is vital for supply chain optimization. Additionally, integrating digital tools for client interaction, as noted by Uwizeyimana and Manirakiza (2021), ensures seamless communication, preventing delays and aligning client expectations with project goals.

METHODOLOGY

Research Design

This study employed a descriptive survey design to assess and describe management strategies and optimization approaches within the construction supply chain of Rwanda's construction projects, with a specific focus on the Amahoro Stadium project as a case study. The design facilitated the collection of detailed data on current practices, challenges, and opportunities, providing valuable insights to inform strategies for optimization in similar construction projects. The study population consisted of 128 individuals and entities involved directly or indirectly in the Amahoro Stadium construction supply chain, including project managers, contractors, suppliers, logistic managers, on-site workers, engineers, government officials, and community stakeholders. A sample of 97 respondents was selected using the Granular formula for sample size determination. Stratified simple random sampling was used to ensure a representative selection from the different categories within the population, while purposive sampling was applied to identify key informants for interviews. This approach ensured that the sample accurately reflected the diverse roles and functions necessary for the project's planning, execution, and completion, enhancing the study's ability to draw meaningful and representative conclusions.

Data Collection Methods

This study employed a mixed-method approach to gather both qualitative and quantitative data using three data collection instruments: individual questionnaires and interview guides. The questionnaires were distributed to a diverse target population, including project managers, contractors, suppliers, logistics managers, on-site workers, engineers, government officials, and community stakeholders. In-depth interviews were conducted with key informants, such as project managers, contractors, and government officials overseeing the Amahoro Stadium project, to supplement the data from the questionnaires. Following approval from relevant management and the university, a recommendation letter was obtained and submitted to Amahoro Stadium management to gain permission for data collection. Ethical considerations were addressed by obtaining informed consent from all participants. A pilot test with 10 respondents was conducted to assess the reliability of the instruments, while the validity was tested using the Content Validity Index (CVI). The questionnaire was reviewed by the supervisor, and items were assigned scores based on their relevance to the study objectives. A CVI score of 0.7 or higher, as recommended by Fisher (2004), was required for the study to be deemed valid.

Data Analysis and Procedures

Once data were collected, edited, cleaned, and validated for completeness. Quantitative information from the surveys were coded before being entered into the statistical product and service solutions (SPSS) software for analysis. Frequencies, percentages, and cross-tabulation were be produced to examine quantitative data. To determine the significance of possible management strategies to optimize construction chain, the chi-square p-value were utilized. Because the researcher employed an ordinal scale of assessment, the Likert Scale, the Spearman rank correlation coefficient will be utilized to test the direction and size of the associations. Tables and narratives were used to present the findings. Qualitative data from open-ended items were examined using content analysis and organized depending on emergent themes.

FINDINGS AND DISCUSSIONS

This section presents the findings derived from the analyzed data, addressing the specific objectives of the study. The analysis is divided into two main parts: the first discusses the influence of logistics on the optimization of the construction supply chain, while the second explores the role of technology integration in supply chain optimization. Descriptive statistics, including percentages, mean, standard deviation, and standard error mean, were used to present the findings, with the standard deviation aiding in the calculation of standard error. Responses were analyzed using a Likert scale, ranging from Strongly Disagree (SD) to Strongly Agree (SA). A standard error less than 2 indicates that the mean is a reliable reflection of the population. For inferential statistics, correlation analysis, regression analysis, coefficients of determination, and analysis of variance were also employed.

Influence of Logistics Management on Optimization of Construction Supply Chain

This section focuses on the findings of a study that examines how logistics management influences the optimization of the construction supply chain. The findings are presented in Table 1.

Table 1: Influence of Logistics Management on Optimization of Construction Supply Chain

Statements	SD	D	N	A	SA	N	Mean	SD
1.Effective transportation influence the optimization of construction supply chain in Rwanda.	0%	0%	21(21.6%)	34(35.0%)	42(43.2%)	97	4.58	0.581
2.Inventory control influence the optimization of construction supply chain in Rwanda.	0%	0%	8(8.25%)	42(43.2%)	47(48.4%)	97	4.52	0.587
3.Risk management and responses influence the optimization of construction supply chain in Rwanda.	0%	9 (9.2%)	5(5.15%)	32(32.9%)	51(52.5)	97	4.66	0.509
4.Demand variability influence the optimization of construction supply chain in Rwanda	11(11.3%)	4(4.10%)	0(0%)	48(49.4%)	34(35.05%)	97	4.28	0.692

Source: Primary Data (2024)

The findings revealed that the majority of respondents (43.2%) strongly agreed that effective transportation optimizes the construction supply chain, with a mean score of 4.58 and a standard deviation of 0.581. This highlights transportation's critical role in reducing delays and minimizing costs in construction projects. Similarly, 48.4% strongly agreed that inventory control influences optimization, with a mean of 4.52, emphasizing its importance in maintaining material availability and preventing delays. Regarding risk management, 52.5% strongly agreed it affects supply chain optimization, with a mean score of 4.66, underlining its role in mitigating potential disruptions. However, 9.2% strongly disagreed, possibly reflecting the challenges in controlling risks in construction. For demand variability, 49.4% agreed and 35.05% strongly agreed that it impacts optimization, with a mean score of 4.28, suggesting that fluctuations in demand can complicate procurement and scheduling. Despite some disagreements, particularly regarding demand variability and risk management, the findings align with existing literature emphasizing the importance of logistics functions in construction supply chain optimization. Qualitative interviews with stakeholders highlighted challenges like poor coordination, delayed deliveries, infrastructure issues, and temporary road closures, all of which negatively affect supply chain efficiency. However, participants also emphasized strategies such as improved scheduling, materials management, and workforce coordination to optimize the supply chain, underscoring the

complexity of logistics management in construction projects and the need for targeted interventions.

Role of Technology Integration Influence Optimization of Construction Supply Chain

Building on the previous analysis, this examination of technology integration in the construction supply chain reveals a consensus among stakeholders on its positive impacts, particularly in enhancing efficiency and adaptability. Furthermore, the emphasis on continuous skill development and training underscores the importance of ongoing capacity building to fully leverage these technological tools. These insights suggest that sustained support for skill development can further optimize the supply chain, ensuring greater flexibility and performance. The findings are presented in Table 2.

Table 2: Role of Technology Integration Influence Optimization of Construction Supply Chain

Statements	SD	D	N	A	SA	N	Mean	SD
1. Information sharing influence the optimization of construction supply chain in Rwanda.	0%	0%	8(8.35%)	36(37.11%)	53(54.62%)	97	4.61	0.549
2. Inventory tracking system influence the optimization of construction supply chain in Rwanda.	0%	0%	5(5.15%)	43(44.3%)	49(50.5%)	97	4.27	0.770
3. Training and skills development influence the optimization of construction supply chain in Rwanda.	0%	2(2.0%)	3(3.0%)	46(47.4%)	48(48.4%)	97	4.21	0.769
4. Automation level influence the optimization of construction supply chain in Rwanda.	8(8.22%	5(5.15%)	0(%)	55(56.7%)	42(43.2)	97	4.25	0.785

Source: Primary Data (2024)

The majority of respondents (54.62%) strongly agreed that information sharing is crucial for optimizing the construction supply chain in Rwanda, with 37.11% agreeing, resulting in a high mean score of 4.61 and a low standard deviation of 0.549. This reflects a strong consensus on the importance of transparent communication among stakeholders such as contractors, suppliers, and project managers in enhancing decision-making, reducing delays, and improving resource

allocation. Information sharing is vital for streamlining material flow, reducing uncertainties, and ensuring timely deliveries, leading to better project outcomes (Khan et al., 2018). Regarding inventory tracking systems, 44.3% of respondents agreed and 50.5% strongly agreed that these systems significantly influence supply chain optimization, with a mean score of 4.27 and a standard deviation of 0.770. This indicates strong agreement, though with some variation in responses. Accurate inventory tracking ensures resources are available when needed, reducing downtime and preventing stock outs or overstocking (Olanrewaju et al., 2020).

Training and skills development also play a key role, with 48.4% strongly agreeing and 47.4% agreeing that it contributes to supply chain optimization, yielding a mean score of 4.21 and a standard deviation of 0.769. Continuous training in new technologies equips workers to improve processes, enhancing efficiency and reducing costs (Love et al., 2017). Automation further supports optimization, with 56.7% agreeing and 43.2% strongly agreeing, resulting in a mean score of 4.25 and a higher standard deviation of 0.785. While automation streamlines tasks and reduces human error, the higher standard deviation indicates varied familiarity with its benefits (Skibniewski, 2020). Overall, the findings underscore the importance of technology integration through information sharing, inventory tracking, training, and automation in optimizing the construction supply chain in Rwanda. These results align with existing literature on the positive impact of digital technologies in reducing lead times and mitigating disruptions (Ghaffar et al., 2018). Interviews with key informants further supported these conclusions, highlighting the benefits of digital platforms, GPS, and logistics software in addressing transportation challenges and streamlining communication on-site.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The optimization of Rwanda's construction supply chain requires a comprehensive approach combining effective logistics management, modern technology, and strong customer management. These factors improve project efficiency, reduce costs, and ensure the timely delivery of high-quality outcomes that meet client expectations. The findings highlight the importance of integrating information sharing, inventory tracking, training, and automation in optimizing supply chains. For policymakers and industry leaders in Rwanda, these insights emphasize the need to foster collaboration between stakeholders, invest in technological advancements, and implement continuous training programs. By adopting these strategies, Rwanda can enhance construction sector performance, reduce delays and costs, and promote sustainable project success.

Recommendations

To enhance the optimization of Rwanda's construction supply chain, various stakeholders must take on distinct roles.

Government: The government can play a pivotal role by creating and enforcing policies that encourage the adoption of modern technologies, such as automation tools and real-time tracking systems, within the construction sector. It can also provide incentives for companies to invest in logistics management and risk mitigation strategies. Additionally, the government can facilitate infrastructure development, such as improving transportation networks, which will support the timely delivery of materials. It can also introduce regulations that promote transparency in

customer management practices, ensuring that construction companies engage with clients effectively throughout the project lifecycle.

Private Contractors: Construction companies are key to implementing the recommendations. They should invest in logistics management systems, including inventory control and transportation, to minimize delays. They are also responsible for adopting automation and digital tools to improve communication and coordination across the supply chain. Contractors should integrate advanced risk management strategies to mitigate disruptions and optimize project timelines. Furthermore, they should actively engage with clients by incorporating feedback throughout the project, ensuring that customer needs are met and relationships are strengthened.

Suppliers and Other Stakeholders: Suppliers, subcontractors, and other stakeholders in the construction supply chain should also support these recommendations by adopting advanced inventory and tracking technologies. They need to ensure that they collaborate efficiently with contractors and clients, providing timely deliveries and maintaining transparent communication.

By fulfilling their respective roles, government bodies, private contractors, and other stakeholders can work together to optimize the construction supply chain in Rwanda, leading to improved efficiency, cost-effectiveness, and project success.

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