THE IMPACT OF STAKEHOLDER INTERACTIONS ON THE SUPPLY CHAIN RISKS OF MEGAPROJECTS IN AFRICA

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ABSTRACT

The successful delivery of megaprojects is frequently impeded by the complex and multifaceted risks associated with their supply chains. These challenges are exacerbated by the diverse network of stakeholders involved, encompassing both internal entities, such as contractors and consultants, and external actors, including governmental bodies and local communities. In the African context, these stakeholder networks are further complicated by decentralized governance structures and the involvement of international funding agencies. This study investigates the intricate relationships among stakeholders in African megaprojects through the lens of social network theory, aiming to understand how these interactions influence supply chain risk management. Online questionnaires administered in Ghana and South Africa produced 120 valid responses. Utilizing a partial correlation network analysis, the research identifies the central stakeholders within the network, examining the nature and strength of their interactions. The findings reveal that stakeholder interactions are predominantly characterized by information exchange, with consultants and clients emerging as pivotal actors due to their high centrality metrics—strength, closeness, and betweenness. These central stakeholders play a critical role in decision-making processes, information dissemination, and risk mitigation strategies within the supply chain. Moreover, the study highlights the significance of both strong and weak ties within the stakeholder network. While strong ties, such as those involving consultants, are key for shaping project outcomes, weak ties, particularly with external stakeholders such as local communities, provide access to diverse information and help identify emerging risks. The robust network model, evaluated through bootstrapping techniques, underscores the reliability of these findings, although it also calls for cautious interpretation due to some variability in edge weight estimations. This research contributes to the understanding of stakeholder interactions in African megaprojects and offers practical implications for improving supply chain risk management. By leveraging the insights gained from stakeholder centrality and interaction patterns, project managers can enhance communication, foster collaboration, and address risks more effectively, ultimately improving the overall success of megaprojects.

KEYWORDS:

Africa; megaprojects; social network; supply chain risks

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INTRODUCTION

The successful delivery of megaprojects is often hindered by various risks associated with the complexities of their supply chains (Othman, 2014). These complexities are amplified by the diverse and extensive network of stakeholders involved. Internal stakeholders such as contractors, consultants, owner organizations, and designer are an integral part of the project team. Conversely, external stakeholders such as end users, governmental authorities, and suppliers while not part of the project team, can impact or be affected by the project (Lehtinen et al., 2019).

In Africa, a more decentralized and somewhat hazy governance structure is the consequence of the involvement of foreign financing agencies, the private sector, and both governmental and non-governmental stakeholders (Mosley and Watson, 2016). Typically, the stakeholders must cooperate in a network of relationships that necessitates coordination (Liu et al., 2021). The complexity of the environment, the unpredictability of regulations, and the rising demands of stakeholders make this partnership essential (Romero-Torres, 2020). The complexity is further deepened by myriads of variables such as environmental uncertainty, technological uncertainty, socioeconomic shifts, and organizational interdependency (Aaltonen and Kujala, 2016; Elia et al., 2021). As a result, interorganizational cooperation, coordination, and collaboration are essential for the successful completion of projects (Castaner and Oliveira, 2020).

The interactions and interrelationships between participants of construction projects determine the overall performance of the projects (Srinivasan and Dhivya, 2020). The success of a construction project depends on many factors, with the relationship between stakeholders being one of the most important. As the number of megaprojects increases, the involvement of stakeholders increases, and their relationships become increasingly complex. Understanding the diverse networks plays a pivotal role in promoting accountability among stakeholders throughout the entirety of the process (Vanclay et al., 2015). Thus, effective stakeholder interactions are essential for mitigating risks and ensuring the smooth execution of megaprojects. However, because these connections are dynamic and interrelated, it is necessary to have a thorough understanding of the multiple levels of cooperation, control, coordination, and teamwork involved. (Ali and Haapasalo, 2023).

According to Miao et al. (2019), the expression 'social network' denotes an established connection born out of interactions between individuals, organizations, and sometimes, the entire society and is hinged on the collaboration and connection among individuals. Social networks create mechanisms for dependability prediction and accountability within the network, generating supply chain risks that directly impact project execution (Demirkesen and Ozorhon, 2017). These networks involve numerous institutions and interactions, facilitating the flow of materials, information, services, products, and finance among stakeholders (Park, 2021). Social network approach provides insights into the roles and influences of various stakeholders, identifying critical connections and potential sources of risks within the supply chain network.

Stakeholder dynamics in mega construction projects are complex, requiring effective management to address interdependencies and mitigate risks (Chinyio & Olomolaiye, 2010). Social network theory offers a valuable framework for analyzing these dynamics, focusing on the patterns and structures of stakeholder relationships (Scott, 2017). Social network analysis (SNA) complements this approach by providing tools to visualize and quantify relationships, uncovering insights into stakeholder influence and network connectivity (Borgatti et al., 2009).

While supply chain risk management in construction has been widely studied, limited attention has been given to stakeholder dynamics using network-based approaches. Existing research often emphasizes individual stakeholder attributes or bilateral relationships, overlooking the broader network structures that influence risk propagation (Pryke, 2005). This study addresses this gap by leveraging SNA to explore stakeholder networks, offering a novel perspective to identify key actors and analyze patterns of collaboration and conflict (Freeman et al., 2010).

Existing literature highlights that collaboration in project delivery is a complex process that requires both proactive involvement and a strong mutual understanding among stakeholders to achieve the desired results for all parties involved (Ali and Haapasalo, 2023). Notwithstanding the significance of these relationships, there remains a gap in the practical understanding of how stakeholder interactions impact supply chain risks in the context of African megaprojects. Thus, the research questions that guide the study are as follows:

1. *What is the main basis of interactions among stakeholders involved in African megaprojects?*
2. *How does stakeholder's position in the social network influence risk management decisions in the supply chain?*
3. *How can social network analysis enhance our understanding of the impact of stakeholder interactions on supply chain risk management?*

This research explores the impact of stakeholder interactions on the supply chain of megaprojects in Africa from a social network perspective. By leveraging social network theory, the study aims to model and analyze the intricate web of relationships that underpin these large-scale projects. This innovative application of social network theory to African megaprojects has never been undertaken, offering fresh insights and practical implications for improving supply chain risk management in this context.

LITERATURE REVIEW

Stakeholder complexity in megaprojects

Stakeholders in megaprojects include individuals, organizations, and groups capable of influencing or being impacted by the project (Ninan & Clegg, 2019). These stakeholders exhibit diverse interests, cultural values, and professional principles, which can lead to conflicts (Mok et al., 2015; Van-Marrewijk, 2015).

Managing stakeholder complexity is pivotal due to the intricate interconnections among stakeholders at different project phases (Mok et al., 2016). If not controlled early, complexity - the main source of project risks and uncertainty - adversely affects project outcomes (Floricel et al., 2016). Despite its importance, stakeholder engagement in megaprojects is challenging due to the sheer number of stakeholders and conflicting expectations (Leung et al., 2013). Effective stakeholder management (SM) fosters collaboration, reduces complexity, and aligns interests with project goals (Mok et al., 2016; Ninan et al., 2019).

Research by Mok et al. (2017) emphasizes the importance of understanding disputes and building consensus among stakeholders. Network analysis is proposed as a method to manage these complex relationships and reduce stakeholder complexity (Mok et al., 2017b). Despite advancements in understanding stakeholder performance in complex environments, significant gaps remain in comprehensively addressing the risks arising from complex stakeholder interactions in megaproject supply chains (Park et al., 2017; Eskerod & Ang, 2017).

SM fosters strong connections, reduces project complexity, and enhances social obligations. However, the complexity and scale of megaprojects lead to intricate interrelationships and conflicts of interest. While recognizing and reducing uncertainty should be the main goal of effective risk management, stakeholders frequently place more emphasis on quantitative risk than the intricacies of multi-stakeholder interactions (Liu & Liu, 2014).

Diversities of culture further complicate these interactions, leading to cognitive limits and risk gaps due to insufficient stakeholder engagement (Dyer, R. (2017). Failure to understand deeper cultural differences among stakeholders can result in opportunistic behavior and inadequate risk management (Carvalho & Rabechini-Junior, 2015). According to De Bakker et al. (2012), risk management improves project outcomes through action, perception, expectation, and relationships.

The unique cultural backgrounds of stakeholders significantly shape their behaviors, expectations, and interpersonal relationships. Organizations that fail to adapt their culture to meet societal and stakeholder needs are likely to fail (Atrian et al., 2016). Thus, incorporating cultural sense-making into risk management practices can mitigate negative risks and enhance project success.

Stakeholder collaboration within megaproject supply chains

Construction supply chains (CSCs) are complex networks of stakeholders—clients, consultants, contractors, architects, subcontractors, and suppliers—linked through various financial, contractual, and informational ties. While collaboration is essential for CSC efficiency and success, persistent fragmentation and inadequate communication remain major challenges (Lee et al., 2018; Behera et al., 2015). The traditional separation of design and construction, combined with misaligned priorities among stakeholders, often leads to inefficiencies, communication breakdowns, and increased project risks (Zhang et al., 2019; Koolwijk et al., 2018).

Effective collaboration enhances project performance by improving constructability, reducing litigation, and fostering better problem-solving. However, the construction sector lags in productivity due to weak supply chain practices and adversarial relationships, especially between contractors and subcontractors (Pal et al., 2017). Globalized supply chains further underscore the need for robust stakeholder integration to mitigate risks and improve efficiency (Kamalahmadi and Parast, 2016).

Studies highlight that supply chain collaboration mitigates risks and drives performance by promoting information exchange and coordination (Li et al., 2016; Fan et al., 2017). Organizational culture plays a critical role in creating cooperative environments for shared decision-making and collective efforts (Faris et al., 2019). Emerging technologies such as BIM, lean procurement, and Industry 4.0 tools enhance real-time communication and information visibility, addressing inefficiencies and enabling sustainable practices (Dallasega et al., 2018; Le et al., 2020; Balasubramanian and Shukla, 2017).

Through frameworks such as organizational learning and transaction cost theories, scholars emphasize the importance of collaborative decision-making, shared benefits, and integration across design, procurement, and construction phases to streamline processes and promote sustainability.

Social network analysis (SNA) in construction: an overview and applications

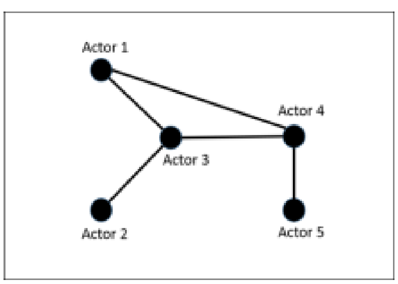
In construction, SNA helps understand the dynamics within project coalitions (Pryke, 2004a), governance (Pryke, 2005), and contractual relationships in public-private partnerships (Chowdhury et al., 2011). Researchers such as Lingard et al. (2014) have applied SNA to analyze contractor networks, revealing how network density and degree centrality impact project outcomes. SNA has proven beneficial for examining the interdependencies of risks arising from stakeholder interactions (Yang & Zhou, 2014), emphasizing its utility in complex projects.

Despite its advantages, SNA's application in risk management, especially in the analysis of stakeholder interactions in megaprojects, remains underexplored (Wang et al., 2019). Thus, filling this knowledge gap is necessary for understanding how social ties influence risk management and stakeholder engagement.

Studies by Anderson et al. (2014) and Chinowsky et al. (2010) highlight the importance of relationship-based analysis and incorporating social factors into project assessments. SNA's ability to classify, visualize, and analyze complex systems (Pryke, 2017) makes it a valuable tool in construction engineering and management. By identifying network limitations and modifying structures, SNA enhances communication and information sharing among project participants (Ruan et al., 2012).

SNA has demonstrated significant potential in uncovering key relational dynamics, communication patterns, and collaborative behaviors within construction projects. It has been instrumental in addressing issues such as stakeholder coordination, knowledge sharing, and risk management, and continues to expand its applicability in exploring the complexity of construction networks. Understanding the interplay between social ties and project dynamics through SNA can lead to more effective stakeholder engagement and successful project outcomes (Adami & Verschoore, 2018). Thus, integrating SNA into construction project management offers a comprehensive approach to addressing relational risks and improving overall project performance. Such a study represents a novel exploration of stakeholder interactions in African megaprojects through the lens of social network analysis. By addressing how stakeholder positions within the network influence risk management decisions, this research uniquely models and analyzes the intricate web of relationships in these large-scale projects. This approach not only identifies critical connections and potential sources of risks within the supply chain but also enhances our understanding of how stakeholder interactions influence risk management.

According to Borgatini and Li (2009), Social Network Analysis (SNA) is a quantitative modeling technique that is systematic and used to evaluate the structural features of supply networks. It is regarded as a helpful technique for comprehending the context in which various stakeholders interact and operate (Wang et al., 2019). The social network analysis method relies heavily on graph theory and matrices to construct the network. Adjacency matrixes and sociograms are two ways to express social network data. A sociogram has both directional and nondirectional linkages. Thus, relationships can be characterized as directed or undirected based on the directionality of the interaction between nodes. A graph that just shows that there is a relationship is said to be non-directional, according to Carter et al. (2007). This network is represented by a symmetric adjacency matrix, in which ties need to be reciprocated (Hanneman and Riddle 2014) (see figure 1 for example). An asymmetric adjacency matrix in a directed sociogram indicates that a tie from "j" to "i" may not always indicate a relationship of the same kind from "i" to "j" (Borgatti and Li, 2009).



	Actor 1	Actor 2	Actor 3	Actor 4	Actor 5
Actor 1	–	0	1	1	0
Actor 2	0	–	1	0	0
Actor 3	1	1	–	1	0
Actor 4	1	0	1	–	1
Actor 5	0	0	0	1	–

Figure 1: Example of sociogram and adjacency matrix
Source: Carter et al. (2007)

As the network is composed of nodes and their relationships, the social network is composed of social actors functioning as nodes and their relationships. According to Ding et al. (2019), a binomial value (where "0" indicates no association and "1" indicates a relationship) may be assigned to the relational data between nodes. Meanwhile, Dang-Pham et al. (2019) argue that Social Network Analysis (SNA) places greater emphasis on the connections within a network than on the attributes of individual nodes. The strength of the association between two nodes can also be shown by a weighted value. In megaproject, social networks consist of a collection of stakeholders and their interrelationships (Xie et al., 2019). Consequently, in this study, each node corresponds to a specific stakeholder, while the level of interaction between nodes reflects the nature of their relationship.

Doloi et al. (2015) identified three primary types of centralities indices used in SNA models to characterize an actor's relevance in a network: Betweenness, Closeness, and Degree. RStudio and R software facilitated the data analysis process. This statistical tool can evaluate structural characteristics of the network across different measurement levels. with adjacent matrices visually displayed to facilitate interpretation (Stein et al., 2011). The adjacency matrix of stakeholders was developed using statistical analysis of the data from the questionnaire survey. Each node in the network represents a stakeholder in the project, and each undirected link (edge) has a weight that represents their degree of connectivity to others. The relationships between stakeholders were measured using centrality and network density measures.

According to Haslbeck and Waldorp (2018), social network analysis improves comprehension of variable interactions across several dimensions and provides insights that traditional data analysis methods frequently overlook. This approach makes use of a graphical network to show the relationships between variables. The network is created using common statistical metrics such as factor loadings, coefficients, correlations, covariances, partial correlations, and regressions (Hevey, 2018). Particularly, partial correlations, which function similarly to multiple regression coefficients assesses the strength of links between variables while controlling for others. This approach not only ensures a comprehensive analysis by accounting for potential confounding variables but also evaluates direct link strengths and identifies mediation pathways, thereby offering a better understanding of network dynamics.

A covariance matrix is a square matrix that systematically examines relationships (covariances) between pairs of variables in a dataset. Each entry in the matrix represents the covariance between two variables, capturing the extent to which they vary together. This tool is particularly useful in understanding the interdependencies of multiple variables, as it provides a foundation for advanced analyses such as principal component analysis and structural equation modeling (Rencher, 2002). In supply chain studies, the covariance matrix can reveal how disruptions in one aspect of the chain, such as supplier delays, correlate with changes in other areas, such as cost escalations or delivery times (Christopher, 2016).

Similarly, partial correlation coefficients measure the strength of association between two variables while controlling for the influence of other variables. This approach is valuable in disentangling direct relationships from spurious ones, especially in complex systems such as supply chains (Cohen et al., 2013). For instance, in mega construction projects, where multiple factors such as stakeholder decisions, financial constraints, and external risks interact, partial correlation can isolate the direct impact of stakeholder actions on supply chain performance. This enables researchers and practitioners to focus on critical drivers of risk and implement targeted interventions (Zhao et al., 2019).

Network properties

Upon estimating the network structure, visualizing the actor enables a deeper examination of the network's characteristics. This assessment reveals critical network properties, such as node centrality (identifying key nodes), overall network density (dense or sparse structures), significant node clusters (communities), and network isolation of individual nodes. Centrality indices are used in networks to assess node importance (Constantini et al., 2015). Social network analysis in this study focuses on three primary centrality indices - strength, betweenness, and closeness. In this study, the edge thickness (as shown later in Figure 2) is indicative of the strength of the association between nodes, through partial correlation. These edges (links) may be categorized as either weighted or unweighted. A weighted edge shows the strength of the connection between nodes, whereas an unweighted edge denotes the existence or absence of a relationship. Differences in line thickness and color density are used to express this strength; thicker and more densely colored lines indicate stronger correlations.

Centrality indices

Central to social network theory in stakeholder analysis is the concept of centrality, which gauges the strength of connections an individual or group holds within a network. Individuals or groups with high centrality typically wield more influence, while those with low centrality may find themselves isolated or possessing less influence. Centrality measures within social networks effectively identify the most pivotal stakeholders among a group, whether they be individuals or organizations (Barranquero et al., 2015).

RESEARCH METHODOLOGY

The study adopts a quantitative method based on social network analysis by administering an online survey questionnaire to key stakeholders in megaproject supply chains in Ghana and South Africa. The social network component is usually ignored in the literature currently available on risk management in megaproject supply chains in places such as Ghana and South Africa, which mostly concentrates on the operational and structural components of supply chain risks (e.g., Tshidavhu & Khatleli, 2020). The paucity of research on megaproject risks in Africa frequently takes a broad view (Babatunde et al., 2019), maybe as a result of the dominance of conventional risk management techniques. Quantitative research allows findings from a sample population to be extrapolated to a larger population (Pittri et al., 2023). By combining purposeful sampling with snowball approaches, the challenge of locating and connecting with stakeholders through conventional means was addressed (Bryman, 2016).

Data source

The study participants included internal and external stakeholders of megaprojects in Africa, with an emphasis on participants from Ghana and South Africa. The African Development Bank (2023) highlights Ghana's expanding infrastructure sector as a critical driver of economic growth, while South Africa's construction industry is influenced by complex socio-political factors. These contrasts provide an important foundation for analyzing how varying cultural, economic, and regulatory factors shape stakeholder engagement in megaprojects. The participants include contractors, clients, suppliers, governmental bodies, NGOs, and community representatives who were considered essential to megaproject supply chains. Out of 220 invited potential participants, 120 provided complete and useful responses. Table I provides comprehensive details of the participants' profiles.

Table I: Profile of participants

Country in Africa where large (mega) project is/was undertaken	N	Percent
Ghana	66	55.0
South Africa	52	43.3
Other:	2	1.7
Total	120	100.0
Highest level of education	-	
Diploma/higher diploma	2	1.7
Bachelor's degree	50	41.7
Graduate (Masters/PhD)	67	55.8
Other:	1	0.8
Total	120	100.0
Total years of experience in the construction industry	-	
1-5 years	4	3.3
6-10 years	7	5.8
11-15 years	22	18.3
16-20 years	30	25.0
More than 20 years	57	47.5
Total	120	100.0
Years of experience in megaprojects	-	
1-5 years	24	20.0
6-10 years	40	33.3
11-15 years	26	21.7
16-20 years	18	15.0
More than 20 years	12	10.0
Total	120	100.0
Type of firm executed or is executing the megaproject(s)	-	
Foreign/overseas firm	22	18.3
Local/domestic	65	54.2
Both	33	27.5

Total	120	100.0
Status of the megaproject (s)	-	
Completed	71	59.2
Ongoing	44	36.7
Abandoned/Suspended	5	4.2
Total	120	100.0
Stakeholder group	-	
Direct stakeholder (Client, Contractor, Subcontractor, Consultant, Supplier, Other)	106	88.3
Indirect stakeholder (Government, Local Community, Media, NGOs, Other)	14	11.7
Total	120	100.0

Data collection

First, a literature analysis was conducted to identify the key players in the supply chain of megaprojects. These stakeholders were considered central to the supply chain of these projects. Secondly, the key stakeholders forming the network nodes (participants in the network) were randomly chosen using snowball sampling. In this method, a limited group of network members was asked to identify additional participants who share a specific relationship. Given that this study looked at social interactions from the perspective of stakeholders, participants were chosen using the stakeholder-based sampling concept (Li et al., 2016). Ultimately, stakeholders who were identified as key megaproject stakeholders in megaprojects in Africa, with their unique IDs included Supplier (Q11), Media (Q12); Local Community (Q13), NGO (Q14); Government (Q15), Subcontractor (Q16), Consultant (Q17), Funders (Q18), Contractor (Q19); Client (Q20).

Subsequently, data was gathered via a questionnaire survey to conduct a comprehensive analysis of the interactions among stakeholders. The participants were instructed to reflect on their past experiences and list all other players they interacted with during the project implementation according to the frequency of interaction. Using a 5-point Likert scale, respondents evaluated the frequency of interactions among principal stakeholders within the megaproject supply chain during the construction phase, with "1" denoting "no interaction" and "5" representing "very frequent interaction". Out of the 220 questionnaires administered, 149 responses were received, but 29 of these were considered invalid. Data collection was carried out through a survey due to its capability to yield extensive information. Participants from the megaprojects were given a structured questionnaire, which was designed to identify the frequencies of communication between each pair of project actors. In the end, the study participants included representatives of stakeholders such as clients, communities, consultants, contractors, funders, government, media, NGOs, subcontractors, and suppliers. It can be seen that over 50% of participants held post-graduate qualifications, and 80% had more than 5 years of experience in megaprojects, which provides confidence in the level of feedback received.

Data analyses

A component of the data gathered from the questionnaire survey was examined using the social network analysis technique. Using the criteria described by Epskamp and Fried (2018), a partial correlation (PC) network was estimated for the survey data. With the bootnet and qgraph packages (Epskamp et al., 2018 and 2012, respectively), the network model was built using the covariance matrix as the input. The undirected and weighted edges in this network represent partial correlation coefficients that reflect the relationships between any pair of nodes, taking into consideration, all other variables in the dataset. This approach ensures a precise depiction of the interconnections among the survey variables (Epskamp & Fried, 2018).

Centrality is a key concept in social network theory and stakeholder analysis; it measures the strength of a person's or group's connections within a network. Individuals or groups with high centrality typically wield more influence, while those with low centrality may find themselves isolated or possessing less influence. Centrality measures within social networks effectively identify the most pivotal stakeholders among a group, whether they be individuals or organizations (Barranquero et al., 2015).

Assessing network structure involves acknowledging the varying significance of nodes. Centrality indices, such as strength, betweenness, and closeness, elucidate a node's relative importance (Borgatti, 2005). Social network analysis methodologies proposed by Epskamp and Fried (2018) and Epskamp et al. (2018) were applied to interpret the data. In this network model, nodes represented stakeholders, and edges depicted interactions between these stakeholders, considering the influence of other nodes within the network. The analysis incorporated ten stakeholder variables, with data processed using R and RStudio software.

ANALYSIS OF RESULTS

Structure of stakeholder interactions and its impact on risk management

Figures 2 and 3 illustrate the partial correlation network and the correlation matrix, respectively, and was based on Spearman rank-order. The network visualization, effectively arranging nodes to enhance interpretability by placing closely associated nodes nearer to each other. This is based on Fruchterman–Reingold algorithm (Fruchterman and Reingold, 1991).

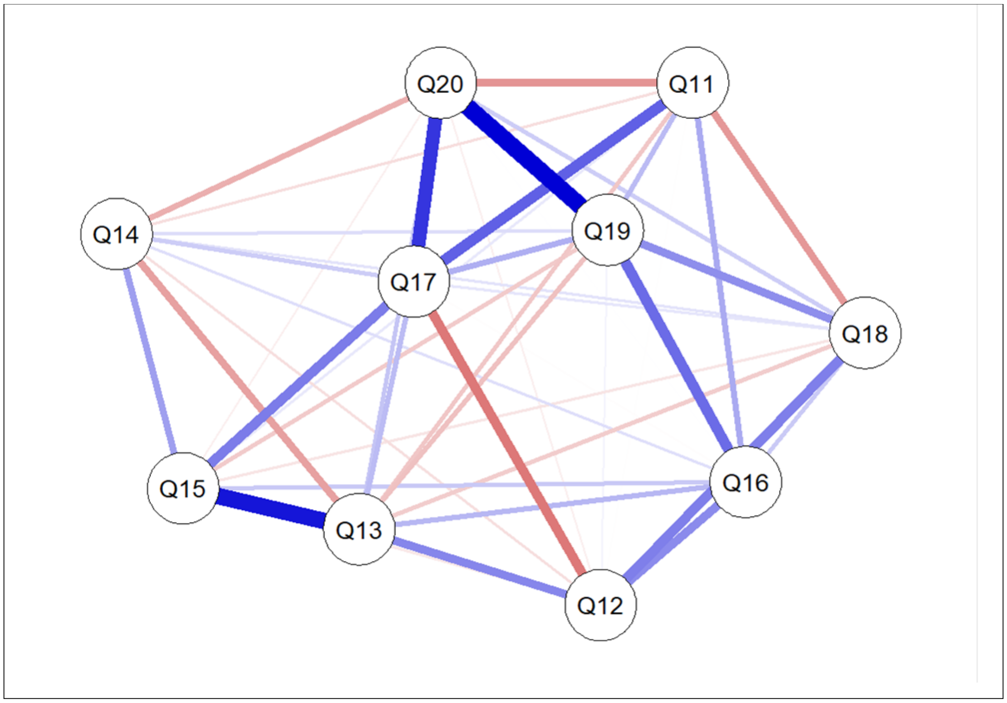


Figure 1: Partial correlation network of stakeholders
Note: Consultant implies Project Manager

Table 2: Definitions of Q Variables

Q Variable	Stakeholder	Role
Q11	Supplier	Provides materials and goods necessary for the project
Q12	Media	Influences public perception and disseminates information
Q13	Local Community	Affected by project outcomes and provides local insights
Q14	NGO	Advocates for social, environmental, or community issues
Q15	Government	Regulates, monitors compliance, and provides approvals
Q16	Subcontractor	Executes specialized tasks under the main contractor
Q17	Consultant	Offers expertise and advisory services for project success
Q18	Funders	Provides financial resources for the project
Q19	Contractor	Oversees construction and project implementation
Q20	Client	Initiates the project and defines its objectives

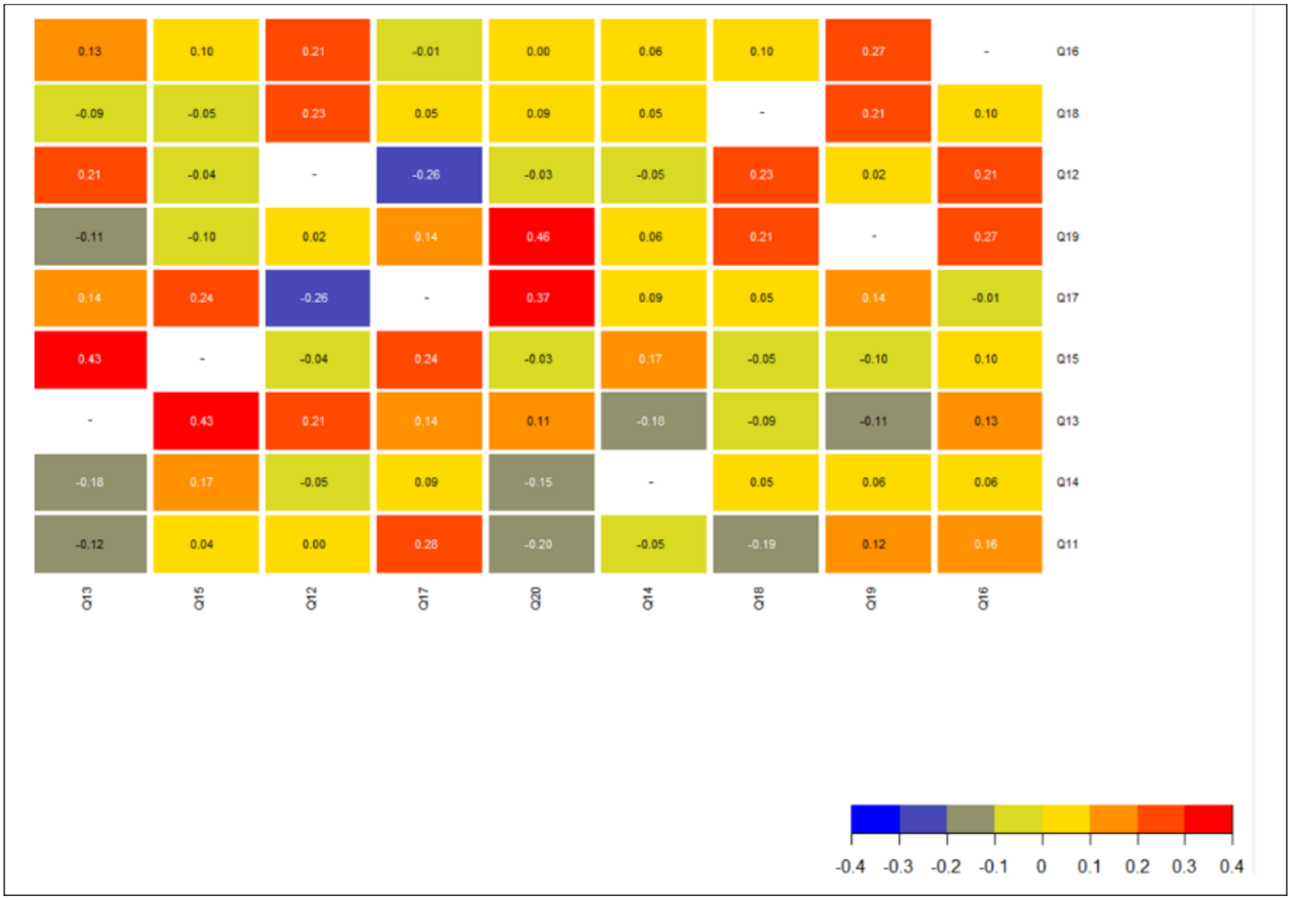


Figure 2 : Partial correlations matrix

The architecture of stakeholder interactions in megaproject supply chains is depicted in a social network graph, where stakeholders (variables) are represented as nodes, each marked with a unique ID number. The interactions among these stakeholders are illustrated by lines (edges), with the thickness of the edges indicating the strength of the interaction. Positive and negative quantitative relationships are color-coded as blue and red, respectively. For example, Figure 2 shows that stakeholders Q19 and Q20 have a positive associated (pc = 0.46), while Q13 and Q15 also display positive association (pc = 0.43), highlighting significant relationships between each pair. There is statistical independence when there is no edge connecting the nodes, suggesting no significant interaction between those stakeholders.

In Figure 3, the color-coded cells illustrate the strength and direction of correlations within the model. Red cells denote the strongest positive correlations, indicating highly impactful relationships, while blue cells represent the most negative associations. These visual distinctions highlight the most significant edges or pairwise comparisons based on their robust correlation coefficients, offering critical insights into the model's key relational dynamics.

Centrality measures

This study evaluates centrality indices, depicted in standardized z-scores (Figure 4), to gauge stakeholders' dominance within the network. Strength indicates the magnitude of quantitative relationships, betweenness denotes intermediary roles, and closeness reflects proximity to other participants. Across nodes, minimal variance exists in these centrality metrics.

Figure 4 illustrates the centrality measures of interest in our study, namely strength, betweenness, and closeness, plotted against the nodes (stakeholders) interaction network in the supply chain, represented by variables Q11 to Q20. Strength, depicted on the x-axis, signifies the sum of all absolute edge weights directly linked to a node. Betweenness, also on the x-axis, represents the count of shortest paths passing through a node. Closeness, on the other hand, displays the inverse of the total distances between a node and all others in the network. The red lines indicate the 95% confidence interval for the observed variable, while the blue line denotes the centrality graph.

In Figure 4, Q17 (representing consultants) demonstrates elevated strength and closeness centrality metrics, along with a relatively higher betweenness centrality index. This signifies its pivotal role within the network, spanning diverse interaction types. Similarly, Q20 (representing clients) exhibits higher betweenness centrality, acting as an important intermediary among stakeholders within the supply chain network, engaging in various interactions.

Major stakeholders play a pivotal role in shaping supply chain networks, exerting significant influence on decision-making, information dissemination, and project success. Understanding their centrality within these networks enables organizations to tailor communication and engagement strategies effectively. By fostering robust relationships with highly central stakeholders, organizations can enhance their own influence within the network. Additionally, these stakeholders are well-positioned to spearhead risk management efforts in megaproject supply chains. Fried et al. (2017) advocate targeting strong nodes for intervention, as they are likely to influence several other nodes. However, Granovetter (1973) emphasizes the importance of weak ties, suggesting that individuals with weaker connections can access diverse information beyond our immediate circles. Hence, leveraging both strong and weak ties is vital for navigating supply chain complexities and maximizing project outcomes.

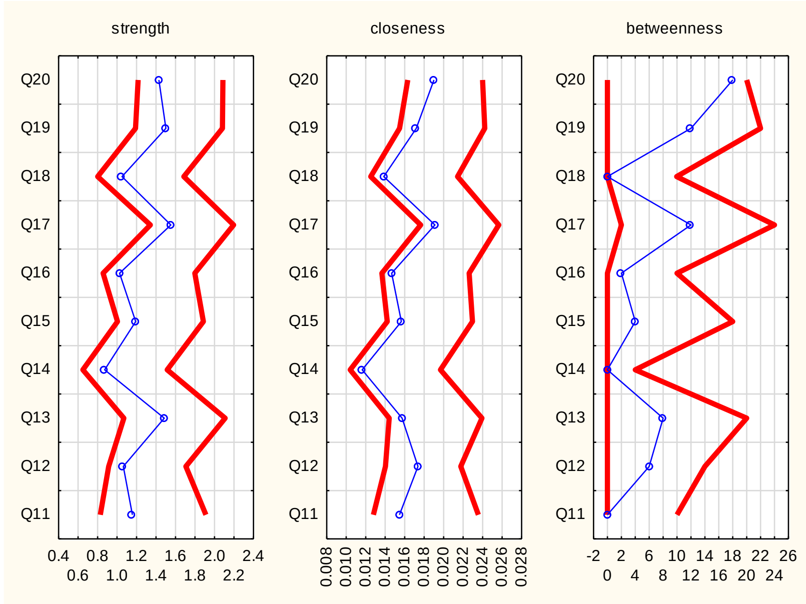


Figure 3: Stakeholders' centrality measures

Edge bootstrap graph (for network accuracy)

We employed the bootnet package to assess the resilience and correctness of our network model, adhering to the technique of Epskamp et al. (2018). This is an important step for comprehensively understanding network estimation and inference in network analysis. Using 1,000 samples, a non-parametric bootstrap method was used to evaluate edge accuracy. The plots produced, along with the 95% confidence intervals (CIs) obtained from the bootstrapping procedure for estimated edge weights, are shown in Figure 5. The horizontal grey area in the plot is the 95% bootstrapped confidence intervals (CIs) for edge weights. Bootstrapping yielded mean values, which are shown by the black curve, whereas observed sample values are shown by the red curve. Additionally, the vertical axis with labels, Q11, Q12, Q13, Q14, Q15, Q16, Q17, Q18, Q19 and Q20 identify represent megaproject supply chain stakeholders.

Most estimated links for measures such as betweenness, strength, and closeness were consistently greater than zero, suggesting reliable estimations. However, a large number of these weights might not differ significantly from one another, according to confidence intervals obtained from bootstrapping. Wider confidence intervals resulting from bootstrapping indicate diminished confidence in estimations, warranting a cautious interpretation of network connections. Thus, wider confidence intervals obtained through bootstrapping caution against drawing definitive inferences regarding the order of most connections in the network.

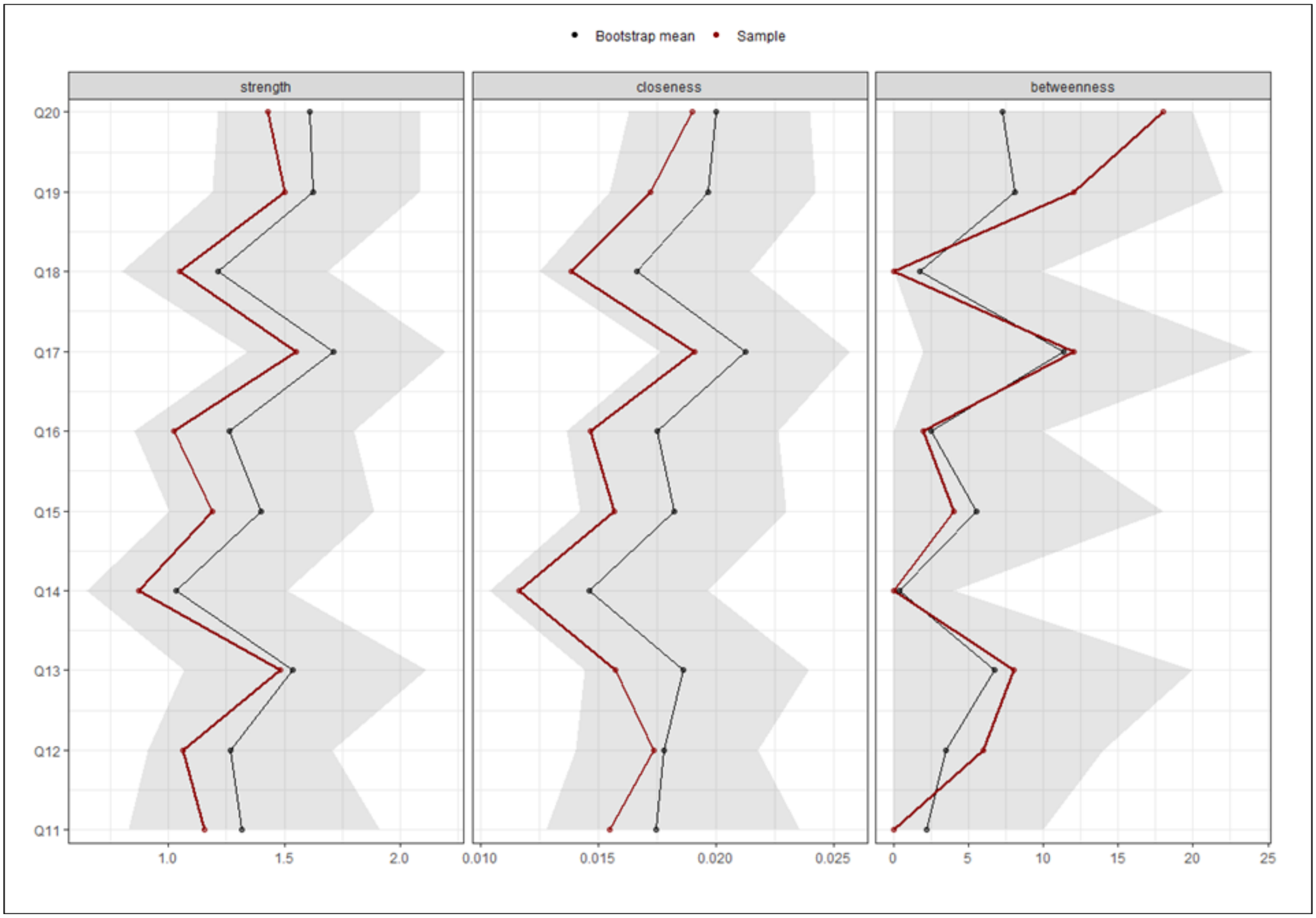


Figure 4: Bootstrap graph

Key drivers of stakeholder interactions in megaproject supply chains

This section highlights the key components that underpin stakeholder interactions in the supply chain during megaprojects. Figure 6 presents a summary of the proportion of participants who stated that their interactions with the following stakeholders were primarily based on information exchange: Consultant (106 participants), Local Community (98 participants), NGOs (93 participants), Media (91 participants), Government (90 participants), Subcontractor (88 participants), Client (87 participants), Contractor (79 participants), Supplier (56 participants), and Funders/Financiers (36 participants). This finding aligns with the established notion in the literature that stakeholder interactions primarily involve information exchange, underscoring the dominance of risks due to communication in megaproject supply chains (see Li et al., 2016; Silungwe and Khatleli, 2018; Wuni et al., 2020). These studies emphasize how communication breakdowns in the supply chain can result in misunderstandings, and inefficiencies which can ultimately threaten megaprojects success.

Among the direct stakeholders in the supply chain, it is evident that consultants are at the center of most information and communication interactions, although local communities continue to play a prominent role within the indirect stakeholders. Additionally, the data demonstrate that different stakeholder groups share information to varying degrees. Consultants are central figures in flow of information among the internal stakeholders, as indicated by the 106 respondents who stated that this is the main way they engage with consultants. On the other hand, local communities are pivotal in information exchange among the external stakeholders in the supply chain, with 98 respondents attributing their interactions. The operational and reputational risks associated with resistance from local community stakeholders can be greatly reduced by addressing community concerns.

The study underscores financial relationships as a prominent aspect of stakeholder interactions within supply chains for megaprojects. Notably, financial considerations emerge as the second most significant driver of these interactions, with a primary focus on clients. This highlights the pivotal role of financial factors in megaproject supply chains, particularly given that clients often represent the most substantial financiers. Discussions on project funding, labor and material costs, and financial negotiations are all part of interactions with clients. Consequently, these findings provide valuable insights for developing effective supply chain risk management strategies, particularly within the intricate social network characteristic of megaprojects.

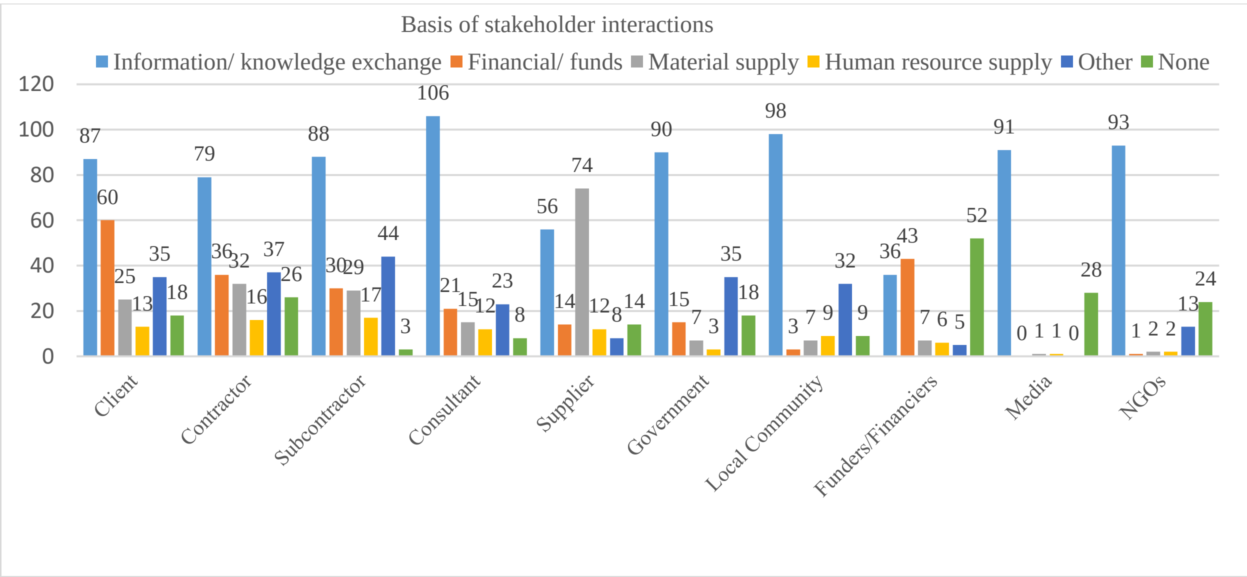


Figure 5: Basis of stakeholder interaction in the supply chain

CONCLUSION

The findings of this research offer a comprehensive understanding of the structure and dynamics of stakeholder interactions within megaproject supply chains and their implications for risk management. Using advanced methodologies such as the bootnet and qgraph packages, the partial correlation network analysis reveals intricate patterns of relationships among stakeholders. The visual representations and centrality measures highlight key stakeholders and their influence, providing clearer understandings the network structure. The study reveals that stakeholder interactions in African megaprojects are predominantly characterized by information exchange. The dominance of information exchange underscores the need for robust communication strategies in mitigating risk arising due to misunderstandings and inefficiencies. The findings further demonstrate that central stakeholders, particularly consultants and clients are pivotal in shaping the interactions within the supply chain. Consultants exhibit high centrality in terms of strength, closeness, and betweenness, positioning them as critical conduits for information and decision-making. This further situates them to potentially wield a pivotal influence in shaping supply chain strategies and mitigating risks. Conversely, the prominence of local communities among external stakeholders emphasizes the importance of addressing community concerns to avoid operational and reputational risks. The findings align with the notion that stakeholders with high centrality can significantly impact supply chain risks management decisions, as they are better positioned to drive risk mitigation efforts and disseminate important information.

One of the most striking findings was the emergence of direct and robust interactions between contractors and clients, effectively bypassing the consultant's traditional intermediary role. This deviation from established norms signals a potential shift in the dynamics of stakeholder relationships within mega construction projects.

A closer examination reveals trust as a pivotal factor in these interactions. The strong connection between contractors and clients may indicate a growing preference among clients for direct communication to ensure their specific goals and concerns are addressed promptly. Conversely, it could reflect a reduced reliance on consultants, possibly stemming from perceptions of inefficiency, misaligned priorities, or a lack of confidence in the consultant’s ability to adequately represent the client’s interests.

These findings call into question the evolving role of consultants in such projects. While their technical expertise remains indispensable, clients and contractors appear to prioritize direct engagement for faster issue resolution and to minimize potential delays in decision-making. This trend highlights the critical importance of fostering trust across all stakeholder groups to enhance collaboration and optimize project outcomes. Stakeholder relationships in megaprojects are shaped by cultural factors that influence decision-making, trust, and communication. Integrating cultural sense-making into risk management helps understand how diverse stakeholders perceive and respond to risks. Social Network Analysis (SNA) is a valuable tool for mapping both formal and informal relationships, revealing cultural nuances in communication, trust, and risk perception.

SNA identifies informal networks that carry culturally specific communication patterns, showing how values such as power distance and communication styles impact risk discussions. It also highlights cultural brokers who facilitate cross-cultural communication and risk mitigation.

By mapping stakeholder interactions, SNA uncovers cultural variations in risk perception, such as differing priorities on long-term sustainability versus short-term cost-effectiveness. Recognizing these differences allows for tailored risk management strategies that account for cultural diversity.

Incorporating SNA into risk management ensures that cultural factors are integrated into communication strategies, improving risk mitigation and providing a deeper understanding of stakeholder dynamics in megaprojects.

The robust network model, evaluated through bootstrapping techniques, confirms the reliability of these findings, although it also highlights the need for cautious interpretation due to some uncertainty in edge weight estimations. The wide confidence intervals suggest that while the identified relationships are generally consistent, further validation may be needed to refine our understanding of the most influential connections.

The study confirms that both strong and weak ties within the stakeholder network play essential roles in managing supply chain risks. Strong ties with stakeholders, including clients and consultants, play a significant role in shaping project outcomes and decision-making processes. Conversely, weak ties, which often involve external stakeholders such as local communities, provide access to diverse information and can highlight emerging risks or opportunities. By identifying both strong and weak ties, organizations can devise more effective risk management strategies, leveraging influential stakeholders to improve communication and address potential risks. Balancing these ties is crucial for navigating the complexities of megaproject supply chains.

Overall, the study underscores the necessity for targeted risk management strategies that leverage the insights gained from stakeholder centrality and interaction patterns. Future research should continue to explore these dynamics by incorporating additional data and methodologies to further elucidate the intricate web of stakeholder interactions and their impact on risk management.

IMPLICATIONS

This study contributes to the existing body of knowledge by providing project managers with insights into inter-stakeholder interactions underpinning megaprojects in Africa. The findings are expected to offer valuable guidelines for leveraging stakeholder interactions to achieving improved risk management through improved stakeholder cooperation, control, coordination, and collaboration in the supply chains of African megaprojects. The findings suggest that project managers and stakeholders should focus on enhancing communication channels and fostering strong relationships with central stakeholders. In order to improve these relationships, integrated management platforms such as BIM would proof beneficial. By prioritizing engagement with key influencers and addressing community concerns, organizations can improve their risk management practices in megaprojects and enhance project outcomes. Additionally, integrating social network analysis into risk management strategies can provide valuable insights into stakeholder interactions and facilitate more informed decision-making.

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