

## Research Article

# Application of Quantitative Models for Enhancing Supply Chain Efficiency and Mitigating Risks in Water Tank Manufacturing Industry of Nigeria

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**Abstract:** The study investigates quantitative models for analyzing the supply chain risks associated with a water tank manufacturing company's facility in Aba, Abia State. Aba, renowned for its bustling commercial activities in the southern part of Nigeria, faces challenges in the supply process due to the combined factors of water tank weight and size. This research explores the intricacies of supply chain management, aiming to identify risk assessment models and vulnerabilities, propose optimal scenarios, and recommend improved risk management strategies. Various methods such as risk factor identification, route time estimation, critical path analysis, cost-related risk assessment, comparison of logistic choices, decision tree analysis, and mitigation strategies were employed to determine the most efficient supply path and reduce costs. The analysis reveals that PATH 6 emerges as the most time-efficient route, with a critical path identified at 62 hours. Results obtained by applying the developed paths to the supply chain mechanism of five major distributors of the company—observing the cost-effectiveness of each path between the budgeted cost, previous cost, and the cost of supplying the goods by following the developed path—show that the budgeted cost and paths cost are closely related compared to the previous cost. For Global Chidozie Nzelu (G.C.N) Enterprise, the overall cost reduction from budgeted, actual, and total path costs stood at 7.89% and 9.44%, respectively. Similar trends were observed for St. Chris Global (S.C.G) Limited (Ltd.) (7.04% and 6.34%), Adiliaba Trading Company (A.T.C) Ltd. (5.76% and 7.31%), Recharad Romeo International (R.R.I) Company (6.07% and 5.46%), and Ndubia Goddy Lines (N.G.L) Ltd. (5.76% and 7.31%), showing a total reduction of 6.851%. This research empowers the water tank manufacturing company in Aba and Nigeria at large, to optimize its supply chain. Furthermore, the implications extend to shaping a more efficient and adaptable landscape for manufacturing industries in the region.

**Keywords:** risk assessment, supply chain management, artificial intelligence, machine learning algorithm, critical path, decision tree model, optimization

## 1. Introduction

In today's globalized and highly competitive business environment, manufacturing companies face numerous challenges like insecurity, unfavorable government policies, bad/inadequate infrastructure, and many other negative

factors, to maintain profitability, enhance productivity, and flexible supply chain mechanisms [1]-[2]. To stay ahead in the market, organizations must continuously seek ways to improve their production processes and supply mechanisms to reduce waste, cut excessive costs, and optimize operational management [3].

The water tank industry, being a type of manufacturing industry that produces an essential but bulky volume component, used in various households, organizations, and companies is no exception to these challenges, as they face movement to end users and dealers.

In response to these challenges, various management tools have emerged, including Computer-Aided Manufacturing (CAM) Software, Production Planning and Scheduling Software (PPSS), Enterprise Resource Planning (ERP) Systems, Manufacturing Execution Systems (MES), Computer-Aided Design (CAD) and, lean manufacturing, Six Sigma, and Quality Management Systems (QMS) [4]-[11]. These tools aim to enhance efficiency, across organizations, foster collaboration, improve decision-making, and digitally transform manufacturing processes by incorporating product development, minimizing lead times, and ensuring quality control, assurance, and continuous improvement [12]-[13].

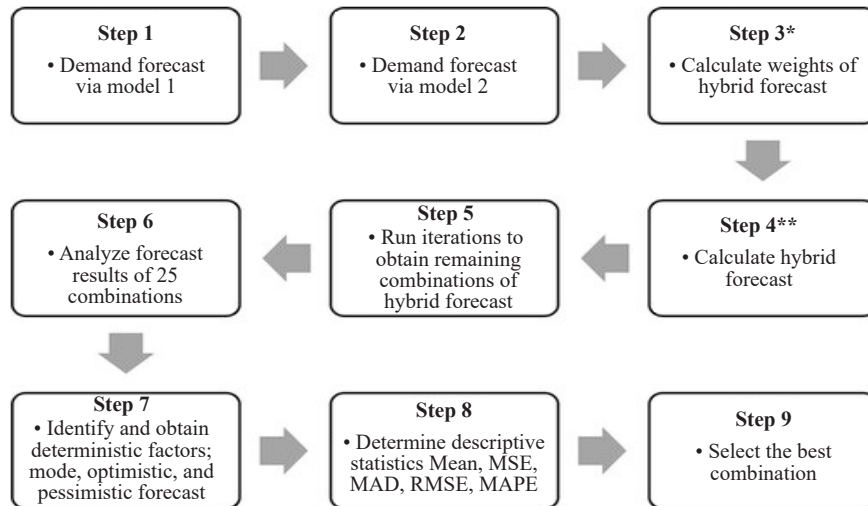
Another crucial management tool for the production industry is Supply Chain Management (SCM), offering a comprehensive approach to planning, implementing, and controlling the flow of materials, information, and services from origin to consumption. SCM involves coordinating and integrating various functions within and among companies to boost efficiency and deliver value to end customers [14]-[15]. The integration of these tools provides a holistic strategy for industries to navigate economic challenges, ensure resilience, and create sustainable growth. Table 1 presents some important key objectives of supply chain management.

**Table 1.** Five main key objectives of supply chain management [16]-[17]

S/N	Item	Definition
1	Collaboration	Fostering collaboration and communication among different stakeholders, including suppliers, manufacturers, and distributors.
2	Risk management	Identifying and mitigating potential risks within the supply chain, such as disruptions or uncertainties.
3	Cost reduction	Streamlining processes and minimizing waste to reduce overall operational costs.
4	Customer satisfaction	Ensuring product availability, timely delivery, and responsiveness to customer needs.
5	Efficiency improvement	Enhancing the speed and accuracy of processes to meet customer demands efficiently.

A quantitative model as an economic and management tool, is designed to assess and manage risks within the supply chain using quantitative data and mathematical techniques, however has gained widespread recognition as an effective approach to enhance productivity and eliminate waste such as time waste in supply chain mechanism [12], [18]-[19].

Some exceptional research has been done to optimize the effectiveness of supply chain management of production industries, which has improved the productivity of companies, such as Azmat and Siddiqui [20], who researched an innovative approach to optimize demand forecasting models, particularly focusing on deterministic factors through Mode and Program Evaluation and Review Technique (PERT). The goal is to enhance accuracy and subsequently improve supply chain efficiency in pharmaceutical operations [21]-[22]. A four-level framework based on deterministic factors is proposed to evaluate the effectiveness of hybrid modeling as shown in Figure 1 on the methodology of the research, in demand forecasting, providing practitioners with valuable insights for decision-making in challenging circumstances.



**Figure 1.** Step-by-step methodology for forecasting hybrid demand [20]

The findings contribute to the flexibility of decision-makers by offering a range of suitable forecasting models and tailoring methods to specific conditions. Additionally, the research underscores the industry's potential to embrace digital technologies, transforming existing forecasting methodologies and ensuring operational continuity, especially during disruptive events like the COVID-19 pandemic [23].

Acquaye et al. [24] developed a quantitative model for environmentally sustainable supply chain performance measurement. This research focuses on developing a robust mechanism for measuring the environmental performance of supply chains, contributing to the shift towards sustainable practices in the global economy. The study recognizes the challenges in measuring environmental performance, such as the lack of standardized methodologies and the multi-criteria nature of the problem. Leveraging a multi-regional input-output framework capable of handling complex and global supply chains, the research presents a comprehensive environmentally sustainable performance measurement model grounded in industrial lifecycle thinking.

Choudhary et al. [25] did an essential job of reviewing some fundamental risk assessments, methodologies, and applications in supply chains. The study discusses the heightened importance of Supply Chain Risk Assessment (SCRA), particularly accentuated by the global disruptions in 2020 caused by the COVID-19 pandemic. Recognizing the increased prevalence of supply chain risks over the past decade, the research conducts a bibliometric and network analysis of SCRA publications. The aim is to identify research areas, underlying themes, and major clusters within the field [26]-[28]. The analysis highlights three significant research clusters, emphasizing parameters, analytical approaches, and multi-criteria decision-making techniques for assessing supply chain risks. By providing interpretation and guidance for future work, the paper serves as a valuable synthesis of SCRA literature. It offers recommendations for researchers and acts as a starting point for operations researchers entering this domain, a trend expected to grow due to the ongoing pandemic [29]-[31].

Artificial intelligence has significantly enhanced supply chain mechanisms by improving efficiency, accuracy, and decision-making [32]-[33]. Through predictive analytics, AI anticipates demand patterns, optimizing inventory management and reducing overstock or stockouts. Machine learning algorithms streamline logistics, enhancing route planning and minimizing transportation costs. AI-driven technologies enable real-time tracking of goods, fostering transparency and responsiveness. Overall, the integration of AI in the supply chain leads to enhanced operational resilience, cost savings, and improved customer satisfaction [34]-[35].

Efpraxia et al. [36] critically reviewed the applications of artificial intelligence and big data analytics for supply chain resilience. This systematic literature review examines the dispersed research on AI and Big Data Analytics (BDA) in supply chain resilience, focusing on studies published in Chartered Association of Business School (CABS) ranked journals. From 522 studies, 23 primary papers were identified, contributing to a comprehensive assessment of the current state of AI and BDA in supply chain literature. The findings categorize the reported improvements of AI

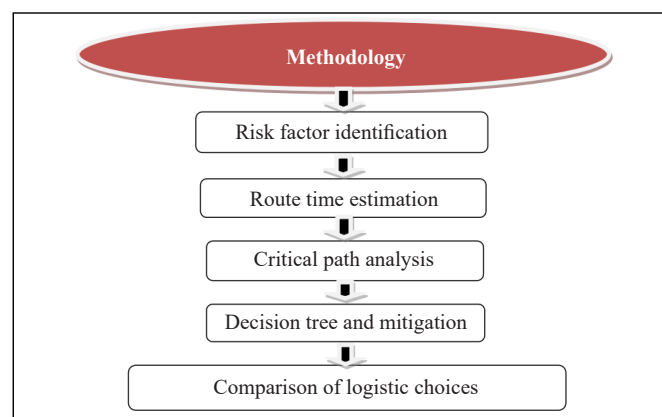
and BDA across different phases of supply chain resilience (readiness, response, recovery, adaptability), providing a synthesized overview of their benefits in this context.

Under empirical investigation, Belhadi et al. [37] developed an Artificial intelligence-driven innovation for enhancing supply chain resilience and performance under the effect of supply chain dynamism. This study explores the crucial role of Artificial Intelligence (AI) in enhancing both Supply Chain Resilience (SCR) and Supply Chain Performance (SCP) amidst dynamic and uncertain supply chain environments. Utilizing the organizational information processing theory, the research employs structural equation modeling and survey data from 279 diverse firms. The findings highlight AI's direct impact on short-term SCP and emphasize its potential for building enduring SCR, thereby contributing empirical insights to maximize AI benefits for sustained supply chain performance. The study recommends further longitudinal investigations to delve deeper into this evolving phenomenon [38]-[40].

While significant research has addressed various aspects of supply chain management, there remains a research gap in the specific domain of water tank manufacturing industries, particularly in Aba, Abia State, Nigeria. Existing studies have predominantly focused on general supply chain optimization, risk assessment methodologies, and applications of Artificial Intelligence (AI) in different industries. However, a dedicated investigation into quantitative models for enhancing supply chain efficiency and mitigating risks in the context of the water tank manufacturing industry in Aba is lacking.

This research aims to bridge this gap by providing a tailored and industry-specific analysis that accounts for the unique challenges posed by the combined factors of water tank weight and size in the supply process. The current literature primarily offers insights into supply chain management in diverse sectors, but a focused exploration of risk assessment models and optimization strategies specific to the water tank manufacturing industry in Aba is essential.

By addressing this gap, the research intends to contribute valuable insights that empower the water tank manufacturing company in Aba to optimize its supply chain effectively. Furthermore, the findings may have broader implications for manufacturing industries in the region, offering a blueprint for enhancing efficiency and adaptability. This research will provide a targeted and industry-specific perspective, adding depth to the existing body of knowledge in supply chain management and risk assessment.



**Figure 2.** Research methodology flowchart

## 2. Materials and method

### 2.1 Methodology

In the pursuit of unraveling the intricacies within the industry supply chain, a meticulous research methodology has been devised. This comprehensive approach aims to navigate through the multifaceted landscape of supply chain management. The ensuing flowchart presented in Figure 2, delineates a systematic path, thereby each step in this methodological journey contributes to the holistic understanding of supply chain intricacies and the formulation of

effective risk management strategies.

## ***2.2 Risk factor identification procedure***

This is the phase where we identify potential risk factors within the water tank manufacturing industry supply chain, thereby a comprehensive analysis to identify and categorize potential risk factors within the industry supply chain was conducted. Furthermore, we utilized industry expertise and historical data to ensure a thorough understanding of inherent risks. Finally, documentation of the identified risks in a structured format for subsequent analysis was established [17]-[18].

## ***2.3 Route time estimation***

Moving forward, we employed quantitative modeling techniques for route time estimation, creating a detailed diagram to estimate plastic tank transportation times across various routes. This involved the utilization of Geographic Information System (GIS) data and historical transport performance, validated through on-site observations and real-time tracking mechanisms [19].

## ***2.4 Critical Path Analysis (CPA)***

The critical path analysis phase followed, incorporating a multi-faceted approach. We developed a comprehensive network diagram, estimated task durations considering precedence relationships, and conducted a forward pass, and backward pass, ultimately identifying the critical path for streamlined transportation efficiency [36].

## ***2.5 Decision Tree and Mitigation (DTM)***

The decision tree and mitigation phase involved the development of a robust decision tree model. This model explored vulnerabilities and proposed mitigation strategies, incorporating key decision nodes related to identified risk factors and critical path elements. Historical data was utilized to assign probabilities to potential outcomes, facilitating effective decision-making [12], [40].

## ***2.6 Comparative analysis***

This verse involves integrating the different paths into the supply system of five different major dealers of the case study water tank company, to observe the cost of following each path, thereby observing their correlation between the budgeted cost and the initial cost of running supply to the dealers.

These variations can arise due to unforeseen circumstances, changes in market conditions, or unexpected events affecting the overall expenditure. Monitoring and analyzing afterward costs are crucial for effective financial management and decision-making, allowing businesses to adapt to changing situations and refine future budgeting processes based on real-world experiences. In this study, budgeted cost variation is very rampant in Abia State commercial areas, due to its populated dens area, where area owners task goods movement, bad roads that would affect the vehicle, instability of petroleum products price, insecurity, and many others that would affect the budgeted cost of the supply.

The questionnaire indicates five major dealers of the water tank which include: G.C.N, S.C.G, A.T.C, R.R.I, and N.G.L, which runs supply to them at least twice a month. The various developed paths were integrated individually into the supply chain mechanism of the individual dealers for one year (January to December 2022), two months for each part and the cost of each supply on each path was observed and recorded. The budgeted and initial cost information was collected from the company's procurement manager from January to December 2021 records, in which the three categories of the costs were validated to see the relationship and effect of each path into the supply system of the company.

### 3. Results and discussion

#### 3.1 Brief description of the case study company and supply path mechanism

Situated in Aba, Abia State, Nigeria, the water tank manufacturing company has a manufacturing facility, multiple warehouses, as well as a network of suppliers, distributors, and retail outlets. The company's primary targets are construction firms, real estate developers, corporations, and individuals engaged in property development or structural establishment. Each of these market segments is vital for cost-effectiveness, considering the substantial investment required to transport products to their ultimate destinations. To facilitate this study, we meticulously selected two warehouses, engaged with five suppliers/distributors, and collaborated with two retail partners.

The Critical path technique was utilized to identify the necessary path in the supply chain that requires minimizing or eliminating risk. The lifeline of the plastic company lies in its supply chain, which has several routes and a diversified supply chain, this may sometimes seem efficient but can significantly affect the operations of the company either negatively or positively. Table 2 presents the supply chain path and time taken to supply the product from the finished production point to its final destination in the central market in Aba, Abia State.

**Table 2.** Supply paths and time taken to get to the expected point

Supply path	Time (hrs.)
A - B	19
A - C	19
B - D	22
B - E	9
C - E	9
C - F	7
D - G	18
E - G	11
E - H	6
F - H	13
G - I	3
H - I	12

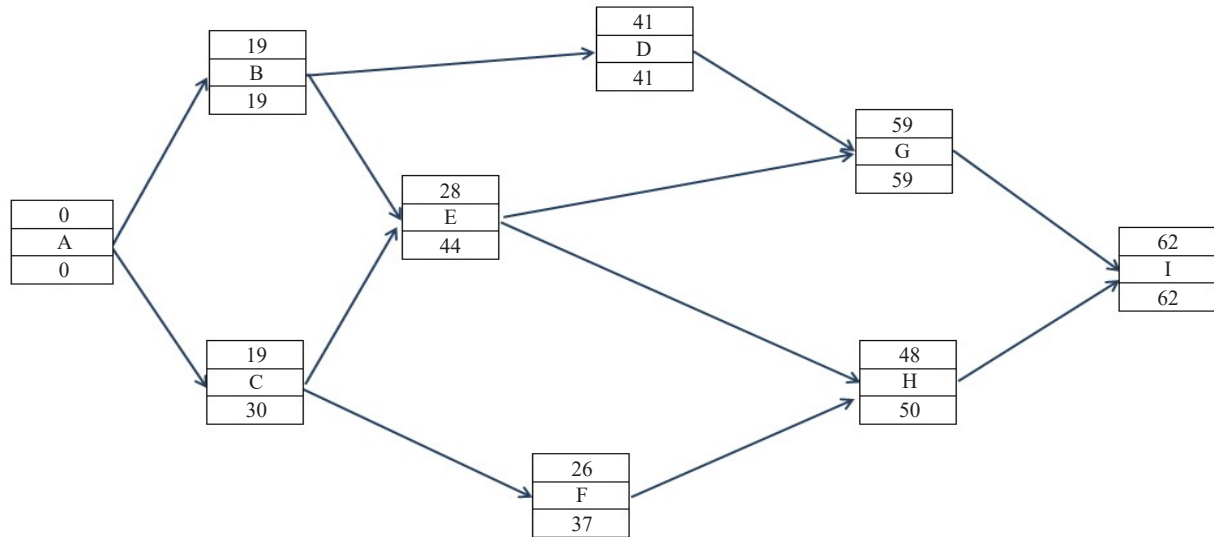
Table 2 shows the time in hours that it takes for the plastic tanks to reach the different destinations before reaching the final consumers or in other words, the time it takes for the company to move the finished tanks from one location to the other, where A is the Factory, B is the Warehouse 1 (W1), C is the Warehouse 2 (W2), D is the supplier 1 (S1), E is the Supplier 2 (S2), F is the supplier 3 (S3), G is the retail store 1, H is the retail store 2, and I is the market.

#### 3.2 Critical path of the system

The critical path method node employed in this research, illustrated in three segmented boxes in Figure 3, served as a tool to gauge time-related risks within the supply chain. These boxes encapsulate the Earliest Start Time (EST), the Name of the Activity, and the Latest Finish Time (LFT), respectively.

The diagram presented in Figure 3 depicts a streamlined representation of XYX company's supply chain,

illustrating the journey of plastic tanks from the manufacturing facility to their ultimate destination, the end consumers in the market.



**Figure 3.** Critical path of the supply chain of the company

### 3.3 Critical paths analysis of the system

This section aims to elucidate the trajectory of the product from the finished product station to its ultimate destination, be it a consumer or business site. Additionally, it calculates the time in hours required for the product to reach the final destination as efficiently as possible, thereby determining the optimal path for operations in terms of minimum time and cost. Table 3 provides details on the different critical paths and their respective durations.

**Table 3.** The critical paths and duration to the final destination

Path S/N	Path stations	Duration calculation (hrs.)
1	A > B > D > G > I	$19 + 22 + 18 + 3 = 62$
2	A > B > E > G > I	$19 + 9 + 11 + 3 = 42$
3	A > B > E > H > I	$19 + 9 + 6 + 12 = 46$
4	A > C > F > H > I	$19 + 7 + 13 + 12 = 51$
5	A > C > E > H > I	$19 + 9 + 6 + 12 = 46$
6	A > C > E > G > I	$19 + 9 + 11 + 3 = 39$

Table 3 indicates that  $\text{PATH } 1 > \text{PATH } 4 > \text{PATH } 3 = \text{PATH } 5 > \text{PATH } 2 > \text{PATH } 6 = 62 > 51 > 46 = 46 > 42 > 39$ . These show us the routes (paths) and the time required for the product to move the factory through a designed path to the final consumers. From the results, it is observed that it takes the plastic company more time (62) hours to move its plastic tank through path 1 (which is also the critical path max), which is the longest time possible in the model while



it takes 39 hours through path 6. For more clarification, the Critical Path Analysis (CPA) of the system is presented in Table 4.

**Table 4.** The critical path analysis of the supply chain

Activities	Duration (D)	EST	EFT (EST + D)	LST (LFT-D)	LFT	Total float (LFT-EFT)	Free float	Indep. float
A - B	19	0	19	0	19	0	0	0
A - C	19	0	19	11	30	11	0	0
B - D	22	19	41	19	41	0	0	0
B - E	9	19	28	35	44	16	0	0
C - E	9	19	28	35	44	16	0	0
C - F	7	19	26	30	37	11	0	0
D - G	18	41	59	41	59	0	0	0
E - G	11	28	39	48	59	20	20	20
E - H	6	28	34	44	50	16	14	0
F - H	13	26	39	37	50	11	9	9
G - I	3	59	62	59	62	0	0	0

Table 4 displays the critical path analysis of the supply chain, revealing the minimum time required for the tanks to transition from one path to another. It also delineates the earliest finish time essential for the movement between different segments of the supply chain. The term “float” denotes the additional time available for transitioning from one destination to another. Paths with zero (0) float warrant careful attention to avoid disruptions in the supply chain process or encountering risks.

The critical path analysis method applied in this research which is presented in Tables 2-3 and Figure 3 follows the systematic process of network analysis from manufacturing to supply system of the selected enterprise applied by Jiří Čejka [42]. The analysis in Table 2 highlights the time efficiency of various supply paths, shedding light on the transit duration from production to consumer endpoints. It delineates each step of the journey, from manufacturing to market, offering insights into optimizing logistics for stakeholders. Furthermore, the result presented in Table 3 and Figure 3, underscores the pivotal routes and associated timeframes crucial for efficient supply chain management, aiding stakeholders in strategic decision-making and risk mitigation. Table 4 further elaborates on the critical path analysis, identifying essential timeframes and potential bottlenecks, thus facilitating proactive measures to ensure uninterrupted supply chain operations.

### 3.4 Results of the comparative analysis between the path and their cost effectiveness

Presenting the detailed cost breakdowns for the supply paths to our major dealers reveals significant insights into the budgeted, initial (actual), and path costs. Each table corresponds to a specific dealer, providing a comprehensive overview of the financial aspects associated with the supply chain.

Figure 4 presents a comprehensive analysis of the supply path to G.C.N. Enterprise and unveils significant trends. Over the six months, actual costs consistently closely matched budgeted costs, indicating precise initial estimations and well-executed supply chain operations. Notably, path costs followed a downward trend, hitting a low of NGN 750,000 in July-August, showcasing potential cost-saving opportunities. Fluctuations in actual costs were observed, attributed



to external factors like market dynamics and transportation costs. The close alignment between budgeted and path costs underscores the success of the developed supply paths, emphasizing their efficiency in cost optimization and suggesting long-term benefits. While this model is well-suited for the case study company’s single-product focus, its applicability may be limited for companies with diverse product portfolios. Therefore, further examination of companies with multiple products is warranted to assess the model’s effectiveness across different contexts. Additionally, continuous monitoring and analysis are imperative for ensuring the sustainability and ongoing improvement of supply chain operations.

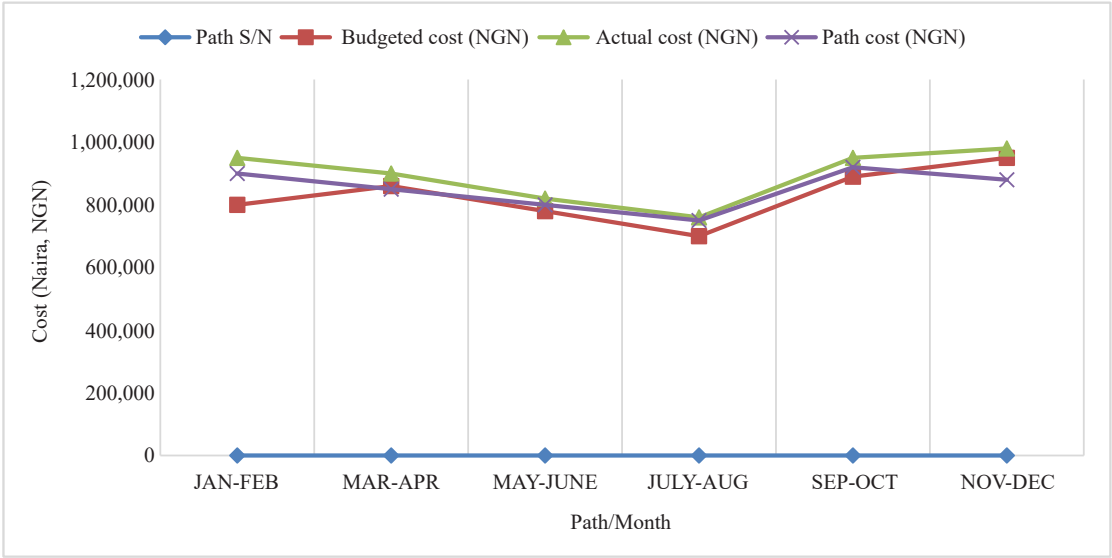


Figure 4. Supply cost comparative to G.C.N enterprise

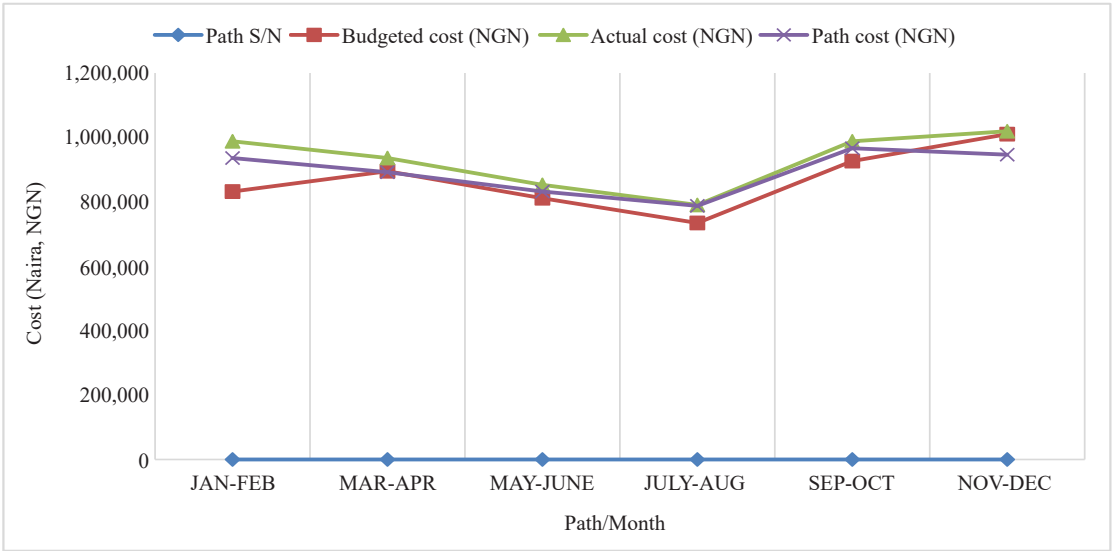


Figure 5. Supply cost comparative to S.C.G. LTD

The analysis in Figure 5 of the supply paths to S.C.G. LTD for each month highlights compelling trends. Notably, the actual or the initial costs closely align with the budgeted costs across the six months, indicating accurate initial

estimations and effective supply chain operations. Additionally, path costs show a consistent downward trajectory, reaching their lowest at NGN 787,500 in July-August, signifying potential cost-saving opportunities. Fluctuations in actual costs throughout the months may be attributed to external factors. The robust correlation between budgeted and path costs underscores the success of the developed supply paths, emphasizing their efficiency in optimizing cost-effectiveness. While the developed model focuses solely on capturing the movement of water products, it is important to acknowledge that the dealer deals in a variety of products. Therefore, future iterations of the model should consider incorporating the movement of other products from different companies to the dealer. By expanding the scope of the model to encompass a broader range of products, opportunities for overall cost reduction across the supply chain can be identified and optimized.

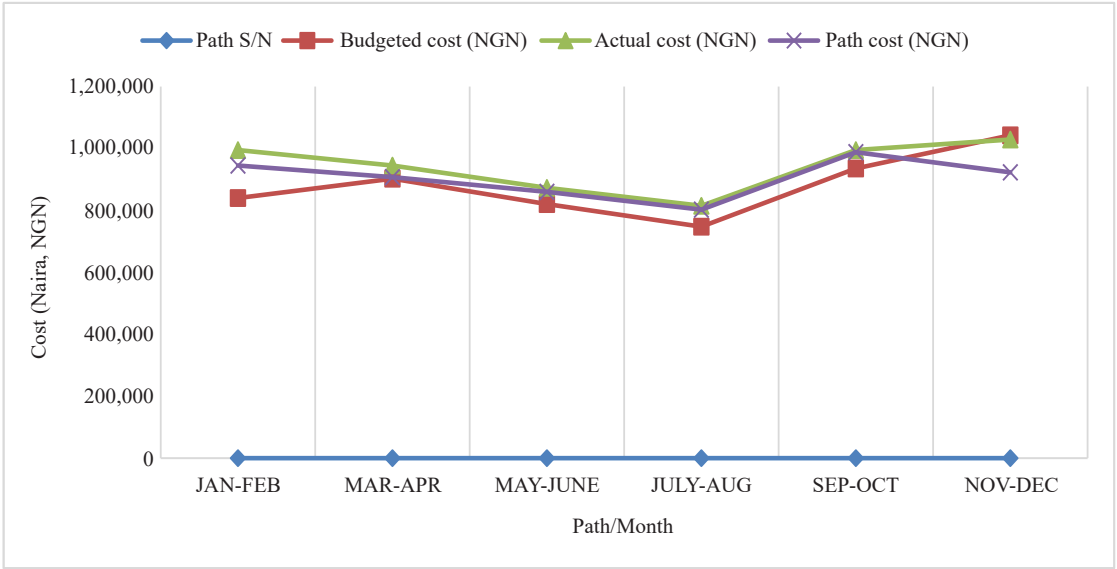


Figure 6. Supply cost comparative to A.T.C company

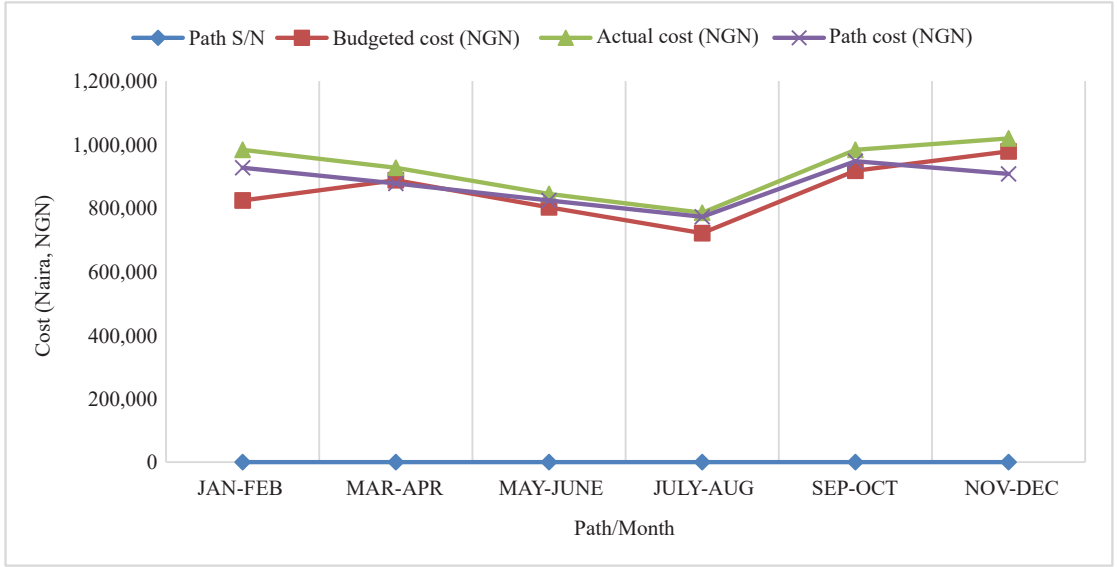
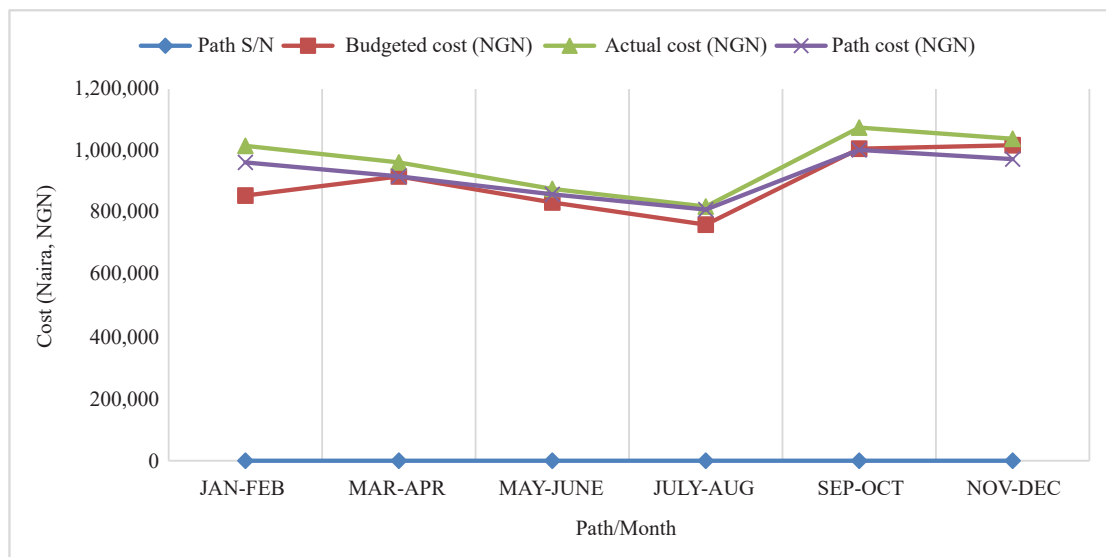


Figure 7. Supply cost comparative to N.G.L LTD

As shown in Figure 6, the analysis of the supply path to A.T.C Company presents significant insights. Over the six months, actual costs consistently align closely with budgeted costs, indicating accurate initial estimations and effective supply chain operations. Path costs exhibit fluctuations, reaching their lowest at NGN 802,500 in July-August, suggesting potential opportunities for cost-saving. Variations in actual costs may be attributed to external factors affecting the supply chain dynamics, and the developed model does not capture all the factors affecting the company's general activity but only the supply chain sector. The robust correlation between budgeted and path costs underscores the success of the developed supply paths, emphasizing their efficiency in optimizing cost-effectiveness.

The examination of the supply path to N.G.L LTD reveals noteworthy patterns and implications. However, over the six months, actual costs consistently align closely with budgeted costs, indicating relatively reliable initial estimations and efficient supply chain operations. However, comparing the path and actual cost (initial cost) with the budgeted cost, the path costs exhibit fluctuations, reaching their lowest at NGN 772,500 in July-August, suggesting potential cost-saving opportunities. Variations in actual costs may be attributed to external factors influencing the supply chain dynamics. The strong correlation between budgeted and path costs underscores the success of the developed supply paths, emphasizing their effectiveness in optimizing cost-efficiency, although the model is homogenous, thereby capturing one unit of the company's operation.



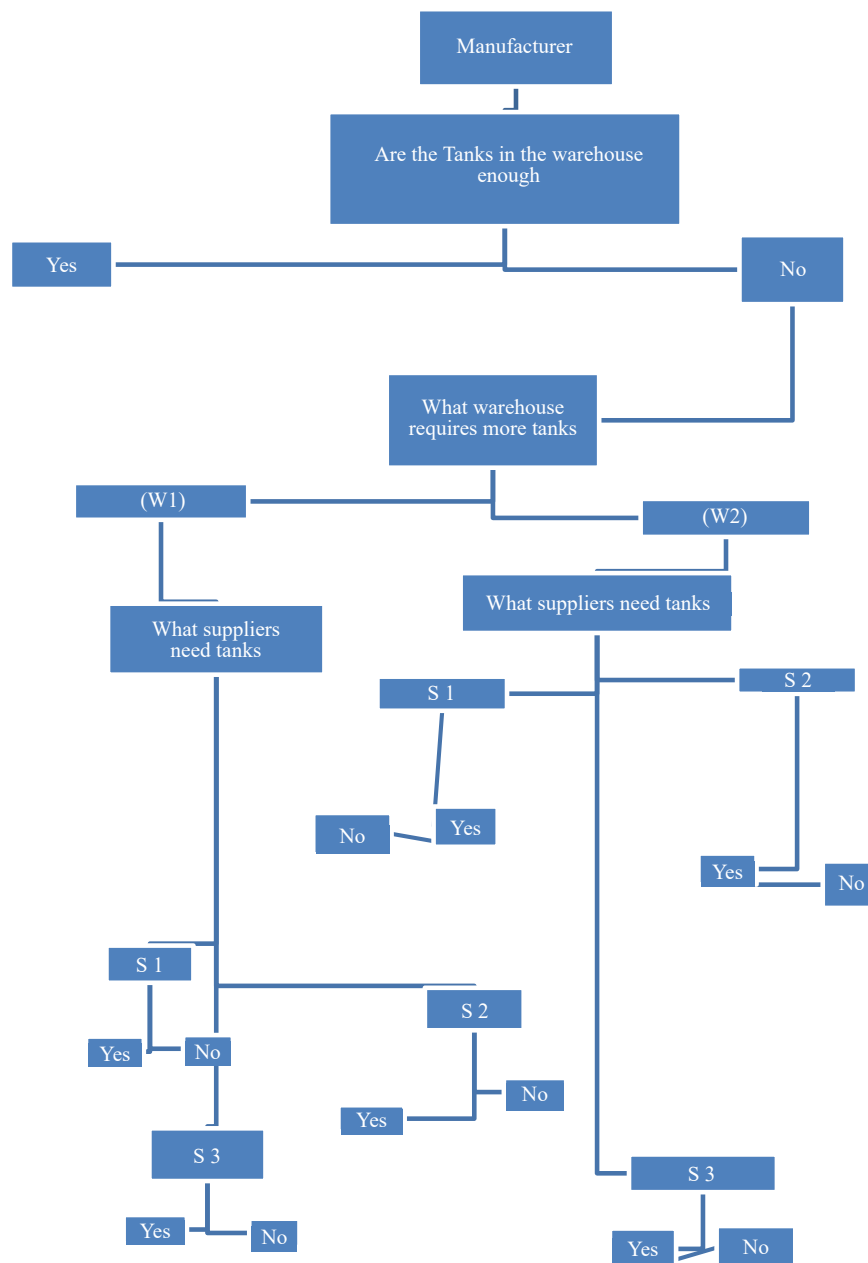
**Figure 8.** Supply cost comparative to R.R.I company

The analysis of the supply path to R.R.I Company highlights significant trends and insights. Over the six months, although, the actual costs consistently align closely with budgeted costs, indicating robust initial estimations and efficient supply chain operations. Notably, path costs exhibit a downward trend, reaching their lowest at NGN 810,750 in July-August, suggesting potential cost-saving opportunities within the supply chain. The higher value in actual costs compared to path cost within the budgeted cost trend may be attributed to external factors influencing supply chain dynamics. The strong correlation between budgeted and path costs underscores the success of the developed supply paths, emphasizing their effectiveness in optimizing cost-efficiency but only on the supply system of the company.

The data presented in Figures 4-8 were sourced directly from the company's procurement manager and portray the monthly budgeted costs, actual incurred costs over the previous year, and the specific costs attributed to each developed supply path. These findings pave the way for a thorough examination and evaluation of the financial efficiency and effectiveness of the supply chain operations to individual dealers.

Furthermore, the result indicates an optimized supply path that benefits suppliers by reducing transit times, enhancing efficiency, strengthening supplier-manufacturer relationships, fostering cost savings, and improving resource

utilization. Also, the manufacturers gain insights to streamline production processes, identify bottlenecks, and optimize logistics, improving throughput, reducing lead times, and boosting productivity and profitability. Moreover, the result depicts efficient supply paths that enable distributors to minimize transit times and inventory holding costs, leveraging real-time data analytics for enhanced delivery reliability, customer satisfaction, and reduced operational expenses. Finally, the customers benefit from a more responsive supply chain with reduced lead times and improved product availability, leading to enhanced satisfaction and loyalty, and ultimately driving business growth and competitiveness.



**Figure 9.** The decision tree of the system

### 3.5 Developed decision tree for the system

The decision tree is used to show the complex choices that need to be taken in order to mitigate risk in the supply chain. For the sake of this research, a simplified version is used.

Figure 9 presents the structural system of the decision tree, in this system, the supply chain manager is tasked with the responsibility of determining whether to request more plastic tanks when the warehouse is out of stock or to fulfill the demands of the suppliers from a different warehouse putting into consideration all factors of production including time and cost. The advantage of the decision tree is that it can be automated, i.e., it can be embedded into systems to create a framework for all possible discussions and ensure that each decision is taken without bias. However, the developed network of the system is limited only to the supply chain of the case study company, considering only the one product which entails that should be needed for more than one product supply company or group of companies.

The presented result underscores the significance of efficient supply paths for suppliers, facilitating streamlined raw material deliveries and fostering stronger partnerships with manufacturers, resulting in cost savings and better resource management. For manufacturers, identifying critical paths and optimizing logistics streamlines production processes, enhances throughput, reduces lead times, and boosts profitability. Distributors benefit from understanding optimal supply paths, minimizing transit times, and inventory holding costs, while leveraging real-time data analytics for route selection to enhance delivery reliability and customer satisfaction, reducing operational expenses. Ultimately, customers experience reduced lead times, improved product availability, and heightened satisfaction, driving business growth, fostering loyalty, and enhancing competitiveness in the market.

## 4. Conclusion

The study thoroughly analyzed the risks and intricacies inherent in water tank manufacturing industries' supply chain management through Critical Path analysis, identifying six distinctive routes with varying time durations for transporting plastic tanks from the manufacturing facility to end consumers. The prioritized sequence of paths, specifically Critical Path 1, followed by Path 4, Path 3 equal to Path 5, followed by Path 2, and finally Path 6, underscored the significance of these specific routes.

These paths were further integrated into the supply chain of five major dealers within a specified timeframe, and their individual costs were observed, comparing them with the normal budgeted cost and the initial cost of supplying from the same route to the dealers. The calculated percentage of budgeted cost reduction from the actual and path costs revealed notable efficiency gains. For G.C.N Enterprise, the overall cost reduction from budgeted, actual, and total path costs stood at 7.89% and 9.44%, respectively. Similar trends were observed for S.C.G. LTD (7.04% and 6.34%), A.T.C Company dealer (5.76% and 7.31%), R.R.I (6.07% and 5.46%), and N.G.L LTD (5.76% and 7.31%).

The effectiveness of the paths against the initial cost can be attributed to a meticulous observation of the supply mechanism, resulting in reduced operation time and mitigated unforeseen circumstances. Notably, the 6th path exhibited the highest cost reduction due to its shorter operational time, emphasizing the crucial role of developed paths in ensuring a meticulous and cost-effective supply chain.

## 5. Recommendations

i. Supply chain managers should incorporate advanced risk analysis and mitigation software with robust algorithms to bolster decision-making and fortify resilience in the face of uncertainties. However, challenges such as initial investment costs and integration with existing systems may hinder the adoption of these technologies. Thus, careful planning and stakeholder engagement are essential to address these barriers effectively.

ii. Embrace a comprehensive approach to decision-making by considering every facet of the supply chain. While this holistic perspective ensures effective risk mitigation and enhances overall supply chain efficiency, challenges such as siloed organizational structures and resistance to change may impede its implementation. Therefore, fostering cross-functional collaboration and providing adequate training and support to employees are crucial to overcoming these barriers.

iii. Extend the application of risk management techniques beyond logistics. For example, manufacturers can collaborate with suppliers to utilize warehouses for storage during periods of abundant raw materials. Similarly, retailers can establish buy-back policies during low-demand seasons to minimize holding costs. However, challenges such as resistance from stakeholders and lack of alignment between supply chain partners may hinder the implementation of these strategies. Therefore, fostering strong partnerships and communication channels is essential to address these challenges effectively.

iv. Enhance efficiency in managing unexpected events, such as rush seasons or demand fluctuations, by implementing streamlined and automated decision processes. Streamlining decision-making contributes to better adaptability and responsiveness to unforeseen challenges. However, challenges such as technological limitations and organizational inertia may hinder the adoption of automated decision processes. Thus, investing in technological infrastructure and providing training and support to employees is essential to overcome these barriers and ensure successful implementation.

## Conflict of interest

The authors declare no conflict of interest.

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