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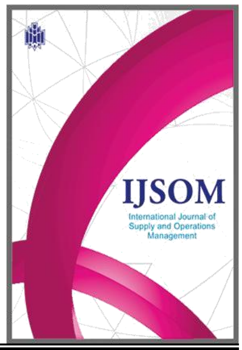

Prioritizing Factors Influencing the Performance of a Supply Chain System using Hybrid Structural Interaction Matrix

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Abstract
Ascertaining and prioritizing the various factors that can influence the performance of a supply chain system is vital towards creating measures that are tailored towards controlling these factors, in order to ensure a sustainable supply chain. This research subject matter has been solved in the literature using multi-criteria decision making techniques, whose prioritization solutions are generated using experts opinions, which are subjective, thereby decision obtained could be prone to biases. In light of this, this study present an Hierarchical Structural Interaction Matrix (HSIM) approach, whose prioritization computation is premised on the theory of subordination derived via systems thinking, to prioritize various factors influencing the performance of a supply chain system. In order to achieve this, firstly, all the factors that could influence the performance of a supply chain system were identified from the literature. Thereafter, a Binary Interaction Matrix, which unveil the arrays of subordinations that exist amidst a number of the identified factors was developed. The result of this exercise was thereafter numerically analyzed using appropriate mathematical equations to determine the intensity rating score of each supply chain performance factor. Furthermore, Pareto analysis was conducted using the latter results, to unveil the vital few factors that could influence the performance of a supply chain system used in an organization. The result of the study unveiled that supply chain performance of an organization can be exponentially improved, if supply chain managers can focus and concentrate their management efforts more on 11 critical factors obtained from the prioritization analyses. With this approach, supply chain manager would obviously reduce errors in the ratings of the supply chain performance-driven factors.

Keywords: Supply chain system; Binary interaction matrix; Hierarchical tree structure diagram; Pareto technique.

1. Introduction

Supply chain performance reflect the capability status of the end-to-end processes of an organization in meeting customers' requirements. If one of the process stations or processes in a supply chain is experiencing problems, then this dilemma will definitely affect or slow down or stop other processes within the supply chain. This assertion is supported by the study of Aramyan et al. (2007) which revealed that the overall performance of a supply chain system is dependent on the functional status of all the end to end processes present in an organization. Hence, in order to ensure sustainable supply chain management, it is vital to have an in-depth understanding of the various factors that influences a supply chain system and the interactions/ relationship that occur among these factors via systems thinking perspective. On the one hand, this knowledge will help supply chain manager to ascertain the degree of importance of each factor towards declining or improving the performance of a supply chain. On the other hand, this knowledge will serve as an eye-opener

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to supply chain managers to ascertain the vital few factors that have high supply chain performance influencing power. As stipulated in the study of Wong and Wong (2008), for the performance of a supply chain system to be sustained, then all the factors that influences the performance of a supply chain system need to be integrated from a holistic point view, to ensure a sustainable supply chain performance management. Existing literature studies had looked at prioritizing supply chain performance factors using the Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Fuzzy-AHP, and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), which requires pairwise degree of importance ranking of these factors using experts' opinions, which is subjective. The subjective nature of expert opinions sometimes limits the accuracy of the prioritized supply chain performance factors. Another limitation is that the usability of such prioritization solution is limited to few stakeholders owing to the subjective nature of supply chain performance factors pairwise ranking. However, no attempt have been made to develop schemes and models that prioritizes various supply chain performance factors using the Hybrid Structural Interaction Matrix (HSIM) technique developed by Ayomoh et al. (2008), which uses principle of subordination and interactions that occurs between these factors, with a view to come up with a widely accepted prioritization solution. In light of this, the present work intends to fill this research gap. In particular, this research work presents a hierarchical prioritization model, which ascertain the hierarchy level of each supply chain performance factor towards improving the performance of the supply chain system of an organization. In addition to this, the study uses the priority weight scores generated from the subordination analysis to ascertain the vital few factors that could exponentially influence the performance of a supply chain system using the Pareto technique. The sections of the paper are highlighted as follows. Section 2 present an overview of supply chain performance management practices available in the literature. Section 3 discuss the concepts of HSIM and Pareto techniques used for the supply chain performance factors prioritization analyses and section 4 discuss the results obtained from the study. The last section of paper, draw relevant conclusions based on the findings of the study and present the future research work.

2. Overview of supply chain performance management

The supply chain performance management literature has been popular for over the past three decades, with myriads of discussions centered around its definition, theory, empirical scrutiny and evaluation approaches (Barber, 2008; Bhagwat and Sharma, 2007; De Leeuw and Beekman, 2008). A summary of the research works on the aforementioned subject matter is presented in the subsequent paragraphs.

The performance of the supply chain system of an organization can be determined using various techniques. These techniques on the one hand include (i) a balance scorecard; which appraises the effectiveness of various activities within a process chain of an organization against the strategic goals of this organization (Gunasekaran et al., 2004, Sezen, 2008, Bigliardi and Bottani, 2014). (ii) Quality Function Deployment (Cagnazzo et al., 2010, Arzu Akyuz and Erman Erkan, 2010); which determines the supply chain metrics, that could improve the performance of the end-end process of an organization, by taking into consideration the key customer requirements, and (iii) Performance Prism; a performance appraisal framework premised on critical assessment of five distinct pillars of supply chain; namely, processes, capabilities, strategies, stakeholder contributions and stakeholder satisfaction (Neely et al., 2001; Kurien and Quresh, 2011). On the other hand, other techniques for supply chain performance measurement and management techniques include: (i) Supply Chain Operations Reference (SCOR); a management tool which appraise the operational performance of an organization, after careful examination of the current state of the companies processes, and goals (Kocaoğlu et al., 2013, Ren et al., 2006, Öztayşi, and Sürer, 2014), (ii) questionnaire; which comprises of myriads of questions tailored towards evaluating the performance of various indicators of a supply chain system (Soni and Kodali, 2010; Tarasewicz, 2016) and (iii) discrete-event simulation (Vernadat et al., 2013; Ramírez-Granados et al., 2014; Ouzrout et al., 2018). The study of Goli and Mohammadi (2021) designed an intelligent system that could be used to evaluate the performance of different supply chain systems that could be used in an organization. The intelligent system uses the combination of a balance score card, path analysis, shapley value and multi-mooral computation schemes to unveil the best policy that will stimulate end-to-end operational process performance improvement. Various quantitative metrics are deployed to evaluate supply chain performance using the aforementioned techniques. According to Kleijnen and Smits (2003), the various time-based measures that could be deployed to evaluate supply chain performance include manufacturing lead time, responsiveness to customers demand, new product development time and delivery speed. The studies of Chae (2009), Gopal and Thakkar (2012) unveiled the quantitative metrics that could be deployed to measure supply chain performance. These metrics include cost, supply chain fill rate, order variance, inventory variance, customer order delivery lead time, bullwhip slope, zero replenishment phenomenon and risk of shortage, resource utilisation rate, throughput/ output rate, raw material and product quality ratio and inventory turnover rate. From another perspective, the study of Rungklin and Srimai (2019) indicated that fill rate, response delay, and stock level and sales/ inventory ratio are the critical metrics that need to be considered to ascertain the performance rating of a supply chain system

There are various factors that could influence the performance of a supply chain system. The study of Bhatnagar and Sohal (2005) and El-Baz (2011) indicated that the qualitative factors such as labor, infrastructure, business environment, political stability, proximity to market, proximity to suppliers, location of the organization and its competitors, demand uncertainty and fluctuations and the effectiveness of manufacturing methods are other variables that could influence the performance of a supply chain system. In addition, the studies of Quesada et al. (2012) and George and Pillai (2019), has identified government support, uncertainty aspects from overseas, supply chain relationship, relationship with suppliers, relationship with customers, flexibility/ adaptability, product quality, logistics, supplier markets, supplier performance, material sourcing, process strategy, customer service, customer satisfaction, supply chain structure, inventory control policy, information sharing, customer demand, forecasting method and review period length, as the factors that influence the performance of a supply chain system. With an attempt to prioritize the various factors that influence the performance of a supply chain system, the study of Singh (2013), deployed Analytical Hierarchy Process (AHP) to prioritize factors that are responsible for managing dependencies between various supply chain members with a view to achieve a coordinated supply chain system. Twenty-three (23) factors influencing the coordination of a supply chain were identified, group into five strategic factors and thereafter prioritized. The result of the study revealed that top management support is the most important factor to achieve a coordinated supply chain, followed by mutual understanding and relationship, flow of information and organization culture. Govindan et al. (2017) prioritised thirty-six (36) performance improvement indicators that have the capability to improve the supply chain performance of an organization using Fuzzy-AHP method. The pair-wise ranking of these indicators were carried out based on the opinions of the supply chain experts within four Indian plastic manufacturing companies. The result of the prioritization exercise revealed that information exchange and collaboration indicators obtained the highest priority weight scores, thereby having more influence towards supply chain performance as compared to the other indicators. The study of Abass et al. (2020) prioritized various indicators that could be used to measure the performance of a supply chain system using the Fuzzy-AHP and the Best-Worst methods. A total of fourteen (14) respondents were used for the pairwise ranking of supply chain performance indicators. The respondents' population were divided into two groups. The result of the supply chain prioritization exercise for the two groups differ in terms of topmost supply chain performance indicator. The first group prioritization result unveiled that customer satisfaction is the most important supply chain performance indicator while the prioritization result of the responses for the second group revealed that overall profitability is the most important supply chain performance indicator. The afore-discussed studies revealed that supply chain performance factors prioritization exercise is premised on human judgement input, which could be biased and subjective, as seen in the study of Abass et al. (2020), which could limit the acceptability of their solutions to small stakeholders. According to Makinde et al. (2019), prioritization of various factors that influences the performance of a supply chain system, based on the principle of subordination and interaction analysis of these factors has received no attention in the literature. To this effect, relevant decision making scheme and model that will indicate to supply chain managers, the vital few supply chain factors (premised on prioritization analysis of myriads of factors), and capable of holistically improving the performance of a supply chain system was sought in this study.

3. Hybrid structural interaction matrix (HSIM) modelling

3.1 Description of the Hybrid Structural Interaction Matrix (HSIM) Methodology

The approach considered in this study is premised on the HSIM methodology introduced by Ayomoh and Oke (2006), and Ayomoh et al. (2008). The HSIM methodology was considered over other decision making techniques owing to its integrated approach premised on systems thinking. It's mode of operation is hinged on the theory of subordination, depicting the flow diagram for pair-wise matrix development and the Hierarchical Tree Structure Diagram for streamlining of the separate factors hierarchy into a consolidate hierarchical diagram (Ayomoh & Oke, 2006). The HSIM methodology actively interrogates the interdependencies and interactions amongst the myriads of factors being examined in this instance, the supply chain performance factors. It utilises a well-formed contextual question that serves as the driver for the pair-wise assessment of any two factors with a view to forming a binary interaction matrix (BIM) via dependency or subordination of one factor relative to another in the supply chain network. Furthermore, a set of mathematical equations deployed in the HSIM scheme (presented in the next sections) are prompted for individual factors weight generation for the purpose of numeric quantification.

3.2 Identified Supply Chain Performance Factors

This section presents the supply chain factors for this research. Twenty-one factors were identified in all and each was briefly described to be sure under which context the factors were utilised in this research. The listed factors were identified from the studies of Quesada et al. (2012) and George and Pillai (2019), since the studies holistically unveiled a wide range of external and internal factors that could holistically influence the performance of a supply chain system, from the SIPOC point of view.

The supply chain performance dependent factors include:

S/N		S/N	
1	Supply Chain Structure	12	Supplier Market
2	Leadership Quality and Top Management Support	13	Supplier Performance
3	Company's relationship with suppliers	14	Material Sourcing
4	Government policy and support	15	Process Strategy
5	Uncertainty aspects from overseas	16	Customer Satisfaction
6	Information Sharing	17	Customer Service
7	Supply chain relationships	18	Customer Demand
8	Relationship with customers	19	Inventory Control Policy
9	Supply chain adaptability	20	Demand Forecasting method
10	Product Quality	21	Inventory Review Period Length
11	Supply chain logistics		

3.3 HSIM Procedure for Factors Prioritization

The step by step procedure required to implement the HSIM prioritization scheme is presented in this section. Figure 1 presents a flow chart that depicts the steps required to carry out the pair-wise interaction of factors prior to creation of a consolidated binary interaction matrix (BIM) of all interacting factors. The BIM is a square matrix that assigns "i" to the rows and "j" to the columns. The BIM is by default assigned a "1" if the response to the contextual question relating factors "i" and "j" is valid and a "0" if response to the contextual question is not valid. The contextual question utilised in this research was defined in terms of CQ_{ij} as presented below:

$$CQ_{ij} = \begin{cases} 1, if\ the\ influence\ of\ factor\ i\ on\ the\ supply\ chain\ can\ be\ directly\ influenced\ by\ factor\ j \\ 0, if\ the\ influence\ of\ factor\ i\ on\ the\ supply\ chain\ cannot\ be\ directly\ influenced\ by\ factor\ j \end{cases}$$

Mathematically, the generalized form of the contextual relationship can be expressed as:

If $i \to j = 1$ then $j \to i = 0$ however,

If $i \to j = 0$ then $j \to i = 0$ or $j \to i = 1$

The formulation of the contextual question is often problem domain centric. Also, by mapping factors "i" to "j" implies the reading of the BIM would be read across the column and vice-versa for a mapping of "j" to "i". The Hierarchical Tree Structure Diagram (HTSD) presented in Figure 2 depicts the steps required to integrate the interacting supply chain factors into a hierarchical order with the most prioritised factor seated at the top most position and vice-versa. A column with more "0s" is considered to be a subordinate to a column with less "0s".

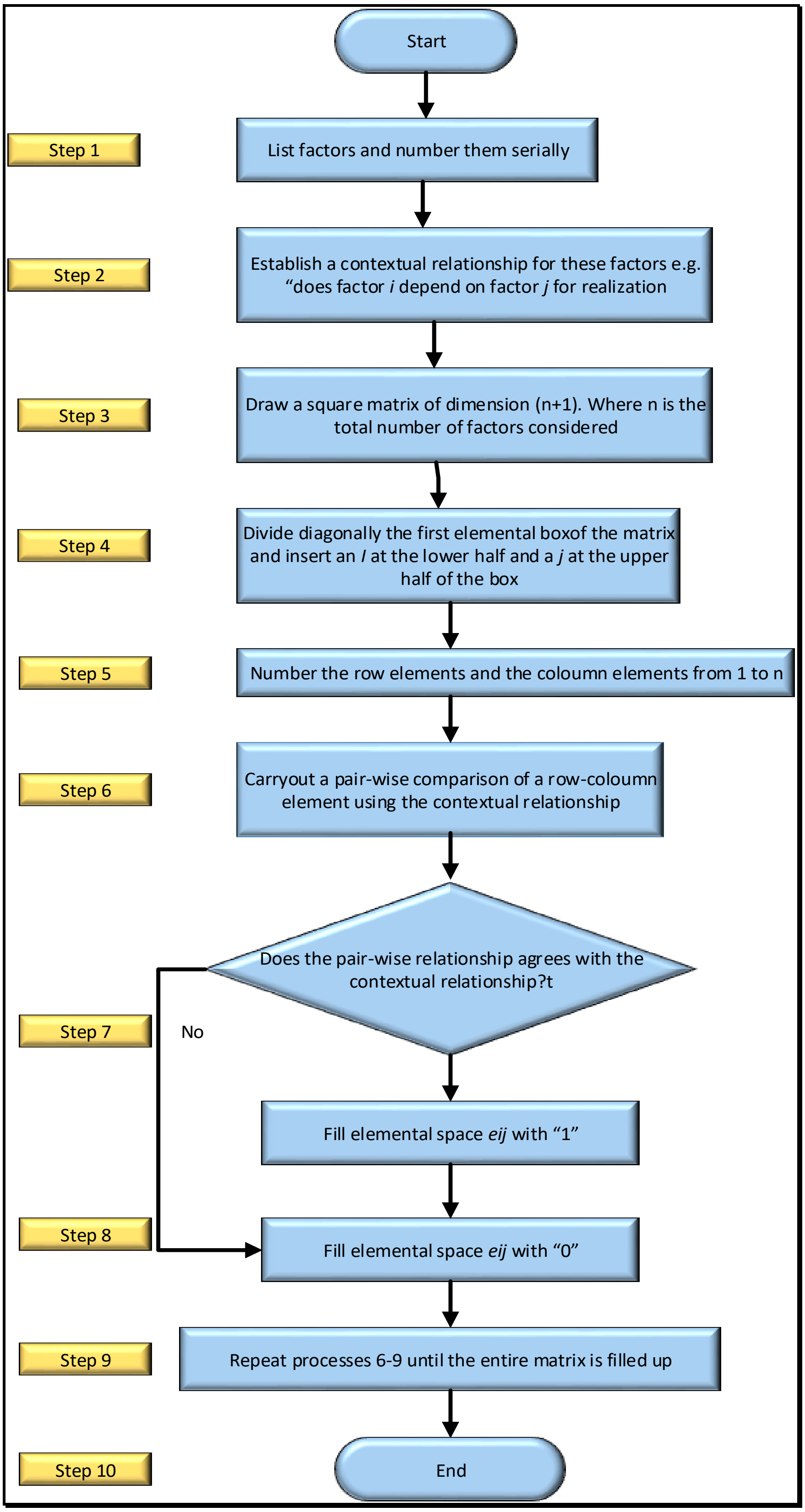

Figure 1. Flow diagram for pair-wise matrix development

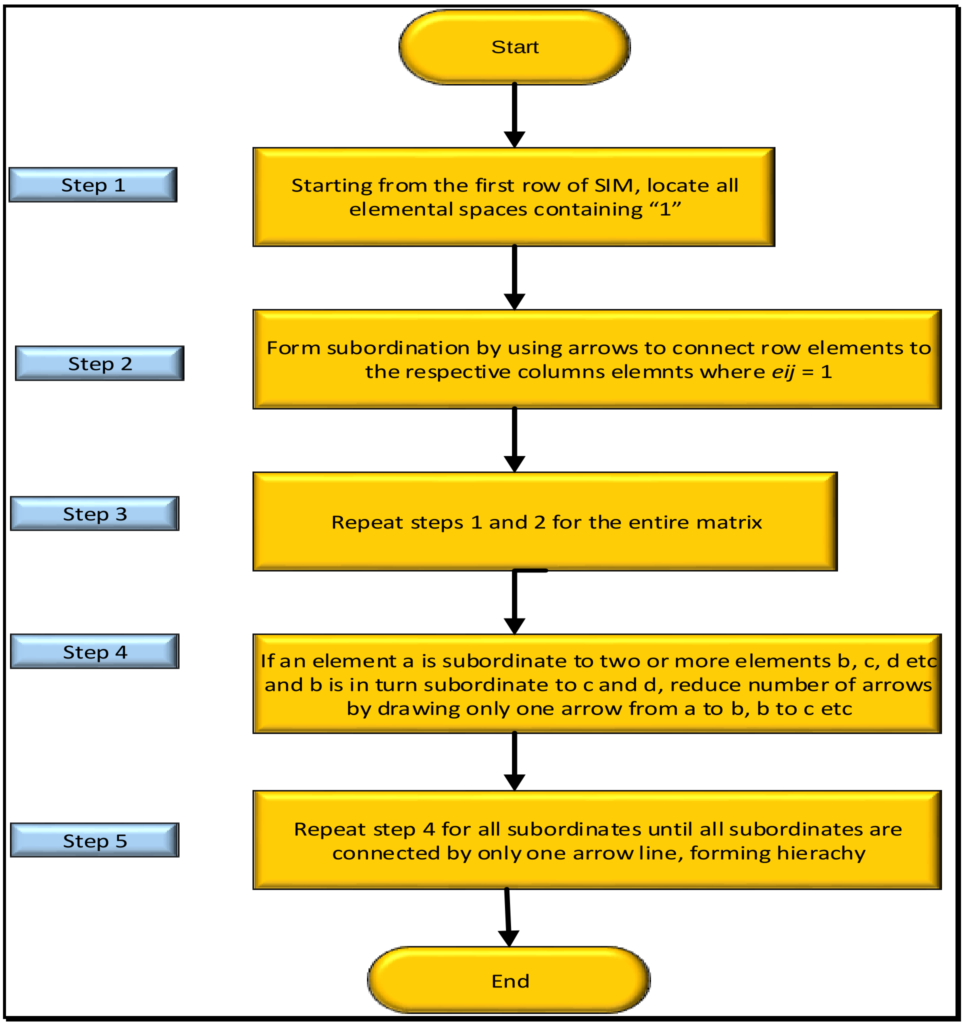

Figure 2. Flow diagram for HTSD framework

3.4 Determination of Weight Per Factor

The weighting model depicted in equation (1) was used to establish the intensity of importance (IR_{F_i}) of each factor influencing the performance of the supply chain system.

$$IIRF_i = \frac{N_{sf(i)}}{T_f} \text{ x } M_{sr} + \frac{a}{T_f}(M_{sr} - \mu) \quad (1)$$

$$a = N_{sf} + 1, \quad (2)$$

$$\mu = \frac{M_{sf}}{T_f} \text{ x } M_{sr} \; ; \quad (3)$$

Where,

N_{sf} is the number of subordinate supply chain factors possessed by a given factor i, T_f is the total number of supply chain performance factors considered in the study, M_{sr} is maximum scale rating and M_{sf} is the maximum subordinating factors. The weighting model is premised on the: (i) the results of HSIM exercise, which establish the number of subordinate factor (N_{sf}) that a particular factor i possess and (ii) the rating of each factor on a scale which ranges between a value of 0 and 9 as indicated in the study of Ayomoh and Oke (2006).

3.5 Determination of the vital few factors influencing the performance of the supply chain system

Pareto analysis was carried out using the intensity rating of each of the supply chain performance factor, to establish the vital few factors, which enormously influence the performance of a supply chain system. Procedure used to carry out the Pareto exercise are as follows:

a) Develop a table as means of capturing your numeric computation prior to building the Pareto Chart.
b) Populate the factors and the intensity rating score for each of the factor in the Table developed in step (a).
c) Rearrange the factors in the descending order of their intensity rating scores.
d) Determine the cumulative intensity rating score based on the result of step (c).
e) Determine the percentage cumulative rating score based on the result of step (d).
f) Develop the Pareto Chart using the results obtained in steps (c) and (e).

4. Result and discussion

4.1 Results of the binary mapping Hierarchical Structural Interaction Matrix for the supply chain performance factors

The result of the pairwise comparison of each supply chain performance factor against one another is depicted in Table 1. This section presents a discussion of results obtained from the developed BIM as contained in Table 1. It further presents results on the computed weights per supply chain factor. Table 1 presents binary outputs of “1s” and “0s” respectively depicting “validity” and “non-validity” of the contextual question in respect of the relationship between the mappings of factors (i) unto (j). Arrays with “1s” depict validity in respect of the contextual question while arrays with “0s” depict non-validity of the contextual question also in respect of the mappings from (i) to (j). From Table 1, it could be seen that factor 1 in the first row has its effect on the supply chain performance directly influenced by factors {2, 5, 18 and 20}. The implication here is that factor 1 is a subordinate to these factors and its effect on the supply chain performance is directly influenced by these factors to different degrees. Factor 2 is not influenced by any factor while factor 3 is influenced by factors {2, 4 and 5}. Factors 4 and 5 are influenced by factors {2} and {2 and 4} respectively. Furthermore, factor 6 as presented on the sixth row is influenced by factors {2, 3, 7, 8, 11 and 15}.

Factor 7 is influenced by factors {1, 2, 3, 4, 5, 11, 15 and 18} while factors 8 and 9 are respectively influenced by factors {1, 2, 4, 5 and 11} and factors {1, 2, 5, 18 and 20}. Others include factor 10, influenced by factors {2, 3, 6, 7, 12, 13, 15, 17}, factor 11, influenced by factors {1, 2, 3, 4, 5, 18}; factor 12, influenced by factors {3, 4, 5, 8, 11, 18, 19 and 20}; factor 13, influenced by factors {2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 15, 18, 20}; factor 14, influenced by factors {2, 4, 5, 12, 18, 20, 21}; factor 15, influenced by factors {2, 11, 18}; factor 16, influenced by factors {3, 8, 9, 10, 12, 13, 14, 15, 17, 20}; factor 17, influenced by factors {1, 2, 4, 5, 7, 8, 9, 11, 12, 13, 15, 18, 19, 20, 21}; factor 18, influenced by factors {2, 4, 8}; factor 19, influenced by factors {2, 4, 5, 6, 8, 11, 13, 18, 20, 21}; factor 20, influenced by factors {2, 5, 8, 18} and factor 21, influenced by factors {2, 5, 6, 7, 8, 11, 18, 20}.

Table 2 is a direct product of the binary interaction matrix as contained in Table 1. It presents the number of subordinating factors (i) corresponding to each factor (j). In the context of this research, a subordinating factor is one that is low on the hierarchical network of all the connected factors. While factors 1 and 2 respectively have 5 and 18 subordinating factors each, factors 3, 4 and 5 respectively have 7, 11 and 13 subordinating factors. Others include factor 6 with 4 subordinates; factor 7 with 5 subordinates; factor 8 with 9 subordinate; factors 9, 10, 11, 12 and 13 respectively with 3, 1, 9, 5 and 4 subordinating factors while factors 14, 15, 16 and 17 respectively have 1, 6, 0 and 1 subordinating factors. Lastly, factors 18, 19, 20 and 21 respectively have 12, 2, 9 and 3 subordinating factors.

Table 1. Pair-wise comparison mapping result for supply chain performance factors

j / i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	1	1	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0
7	1	1	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0
8	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
9	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
10	0	1	1	0	0	1	1	0	0	0	0	1	1	0	1	0	1	0	0	0	0
11	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

12	0	0	1	1	1	0	0	1	0	0	1	0	0	0	0	0	0	1	1	1	0
13	0	1	1	1	1	1	1	1	1	0	1	1	0	0	1	0	0	1	0	1	0
14	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1
15	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
16	0	0	1	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	1	0
17	1	1	0	1	1	0	1	1	1	0	1	1	1	0	1	0	0	1	1	1	1
18	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	1	0	1	1	1	0	1	0	0	1	0	1	0	0	0	0	1	0	1	1
20	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
21	0	1	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	1	0	1	0

Table 2. Number of Subordinate Factors possessed by each Supply Chain Performance Indicator

Factor number	Number of subordinate factors	Factor number	Number of subordinate factors
1	5	12	5
2	18	13	4
3	7	14	1
4	11	15	6
5	13	16	0
6	4	17	1
7	5	18	12
8	9	19	2
9	3	20	9
10	1	21	3
11	9		

4.2 Hierarchical Tree Structure Diagram (HTSD) for the Supply Chain Performance Factors

The HTSD presented in Figure 3 has thirteen (13) priority levels. Factor 2 (Leadership Quality and Top Management Support) is the most prioritized factor while factors 10 and 16 (Product Quality and Customer Satisfaction) are the least prioritized factors due to their high level of dependence on other factors. Leadership Quality and Top Management Support is a major determinant of success in any supply chain system. Poor leadership skills and inadequate support from the top management can result in retrogression of any given system. Closely followed, is factor 4 (government policy and support). This factor is on the second priority level and a direct subordinate to leadership quality and top management support. With respect to factor 4, the series of reforms, regulations, norms and policies implemented by the government of a country could either encourage or discourage international trade for sourcing resources from other countries. This act could have a high impact on a couple of other supply chain performance factors, especially on customer organization decision on whether to purchase raw materials from overseas suppliers or not (factor 5). Next to this is factor 18 (customer demand) and factor 5 (uncertainty aspect from overseas) positioned on level 3 of the hierarchy diagram. Increased visibility and understanding of fluctuating demands is pivotal to prevent amplification of order variance (referred to as bullwhip effect) throughout the supply chain. Political uncertainties in customer and raw material organizations can be detrimental to the success of a whole lot of other supply chain performance factors present in the system.

Next is priority level 4 which comprises of factors 8, 11 and 20 (Relationship with Customers, Supply Chain Logistics, and forecasting method). Establishment of cordial relationship between customers and suppliers organizations ensure smooth, frequent and effective communication between these players, thereby stimulating adequate and accurate information flow and coordination of supply chain activities within the end-to-end processes of an organization, which thus results in production of high quality products. Poor forecasting of customer demand could result in distorted raw material order quantity, which could thus result in order variance amplification across the supply chain of a particular organization. It can also be inferred that company's relationship with supplier (factor 3) cannot be underestimated owing to its key role in influencing a number of other supply chain factors. Closely followed, is the process strategy used in an organization (factor 15). This factor has its significance premised on the overall performance, productivity and profitability enhancement of the supply chain system of an organization.

Next on the prioritized hierarchy are factors 1 (Supply Chain Structure), 7 (Supply Chain Relationship) and 12 (Supplier Market). Factor 1 is directly linked to factor 20 (forecasting method) based on the fact that the accuracy of a demand forecast could influence the supply chain structural configuration in terms of number of process stages, and structure of material and information flow. Factor 7 is directly linked to factor 15 (process management strategy) because the approach deployed to coordinate and manage activities by a supply chain manager could influence the Level of relationship that exist within supply chain processes. Factor 3 is directly linked to factor 12 (company's relationship with suppliers) because an effective supplier relationship with customers would make supplier organizations aware about the real-time needs and changing requirements of the customers, in which in some instance is tailored towards reducing cost as well as rapidly producing new products of high quality. Furthermore, information sharing (factor 6) and supplier performance (factor 13) are both on the 8th priority level of the hierarchy diagram. However, information sharing is an important factor since its primary role is to connect the supply chain partners, thereby allowing them to coordinate their activities towards meeting customers demand. This factor can greatly influence the inventory status review period (i.e. inventory review period length, which is on the 9th priority level) owing to the need to meet changing customers' requirements in a turbulent market environment hence, greatly impacting on the level of productivity. The higher the number of highly fluctuating products demand produced in an organization, the more the need to ensure frequent information sharing among supply chain planners, and the higher the inventory review period length. Supplier performance can greatly influence the amount of inventory stocks that a supplier organization need to hold at a particular period (i.e. inventory control policy which is on the 10th priority level). Successful supplier performance results into high sales and high customer demand pool, which could thus influence the amount of inventory stocks held in a supplier organization. On the other hand, factor 1 (supply chain structure) can significantly impact on the degree of the responsiveness in terms of velocity, versatility, flexibility and resilience of a supply chain system (i.e. factor 9: supply chain adaptability).

Level 10 presents factor 19 representing (inventory control policy) while level 11 present factor 14 representing (material sourcing) and factor 17 representing (customer service). Decision taken by procurement managers on 'when' and 'how much to order'; i.e. inventory control policy (factor 19) could influence the period of carrying out service operations; customer service (i.e. factor 17 which is on priority level 11), tailored towards meeting customers demand requirements. The use of periodic and perpetual inventory systems assists procurement managers to optimally ascertain 'when' and 'how much to order', thereby lowering to the barest minimum the chances of stockout, that could results in downtime and production loss, in an organization. Importing raw materials, components and products from overseas by customer organizations, in pursuit of low cost resources, tends to increase customer organization dependence on the supplier organization. Various risks such as political and economic stability, transportation delays, foreign exchange rates and culture and language could limit the success of material sourcing from oversea supplier organization. This factor influences the customer satisfaction level (factor 16 which is on priority level 13) since customers' gives value to delivery date certainty and low cost. The lower the cost of sourcing the raw materials by the customer organization from the supplier organization, the lesser the cost of producing the final products demanded by the external customers while higher transportation delay experienced during the shipping of raw materials could reduce the chances of delivering the final products at specific date required by the external customers. Lastly, factor 10 (i.e. product quality) and factor 16 (customer satisfaction) are on the priority levels 12 and 13. The influence of all the other factors high up the hierarchy could influence the quality of product produced in an organization, which could therefore have an impact on the customer satisfaction level.

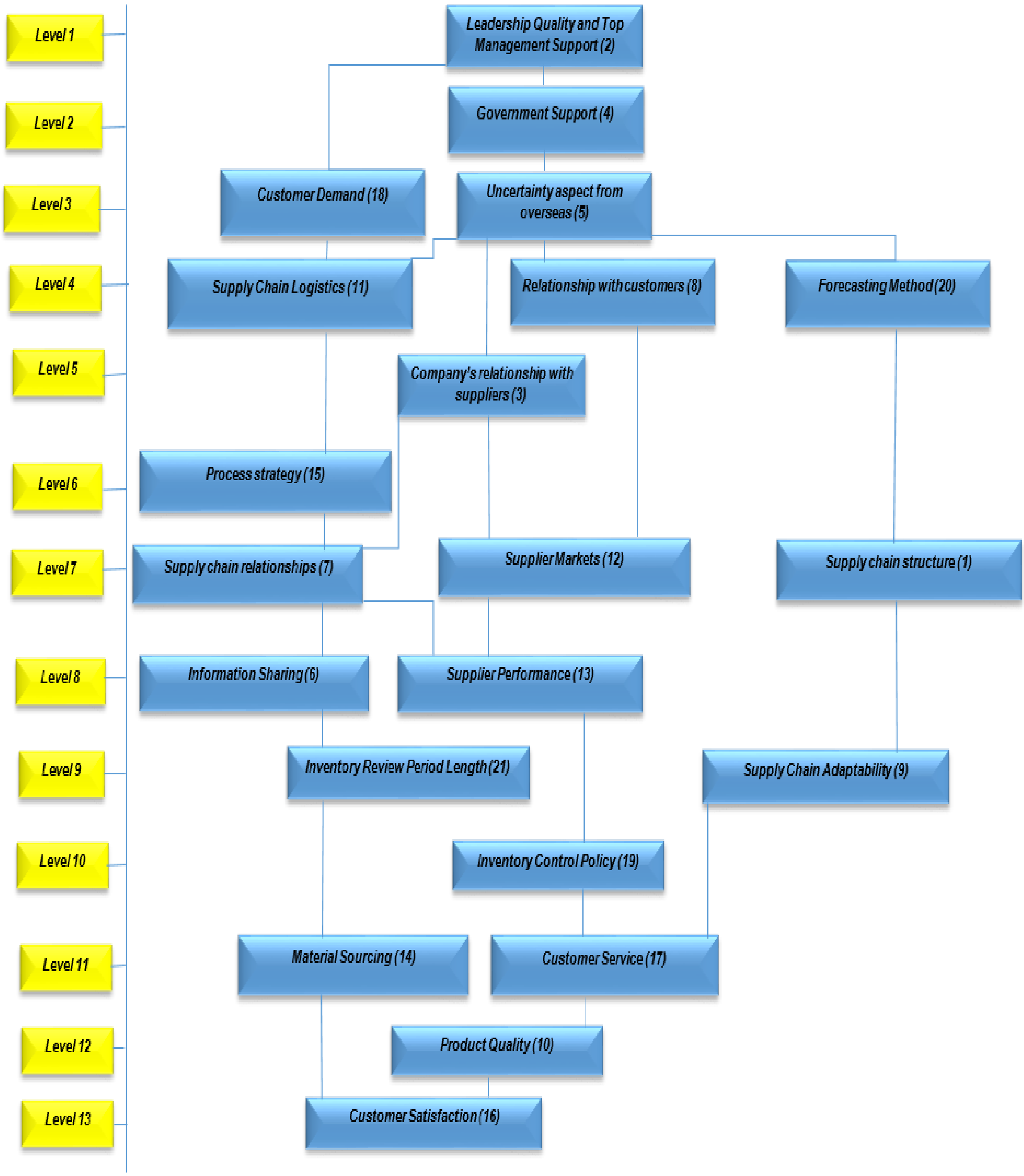

Figure 3. HTSD for the prioritised factors of the supply chain system

4.3 Intensity rating results for each of the Supply Chain Performance Factors

The results of the intensity rating of each factor, which indicates the degree of importance of these factors influencing the performance of the supply chain, based on the results obtained in Table 2 and using equation (1) is depicted in Table 3. Based on Table 3, it could be inferred that the intensity rating of supply chain performance factors 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22 are 2.510, 8.877, 3.490, 5.449, 6.428, 2.020, 2.510, 4.469, 1.531, 0.170, 4.469, 2.510, 2.020, 0.170, 3, 0.061, 0.170, 5.939, 1.041, 4.469 and 1.531 respectively.

4.4 Pareto Analysis of the Critical Factors influencing the Supply Chain Performance of an Organisation

The results of the Pareto analysis, obtained through numerical analysis of the intensity rating of supply chain performance factors are presented in Table 4 and illustrated in Figure 4.

Table 3. Intensity of Rating for each Supply Chain Factor

Factor Number	Rating	Factor Number	Rating
1	2.510	12	2.510
2	8.877	13	2.020
3	3.490	14	0.170
4	5.449	15	3.000
5	6.428	16	0.061
6	2.020	17	0.170
7	2.510	18	5.939
8	4.469	19	1.041
9	1.531	20	4.469
10	0.170	21	1.531
11	4.469		

Table 4. Pareto Table for the Supply Chain Performance Factors

Factor Number	Re-ordered intensity rating in descending order	Cumulative intensity rating	Percentage (%) Cumulative intensity rating	Factor Number	Re-ordered intensity rating in descending order	Cumulative intensity rating	Percentage (%) Cumulative intensity rating
2	8.877	8.877	14.13	12	2.510	54.120	86.13
5	6.428	15.305	24.36	6	2.020	56.140	89.35
18	5.939	21.244	33.81	13	2.020	58.160	92.56
4	5.449	26.693	42.48	9	1.531	59.691	95.00
8	4.469	31.162	49.59	21	1.531	61.222	97.43
11	4.469	35.631	56.71	19	1.041	62.263	99.09
20	4.469	40.100	63.82	10	0.170	62.433	99.36
3	3.490	43.590	69.37	14	0.170	62.603	99.63
15	3.000	46.590	74.15	17	0.170	62.773	99.90
1	2.510	49.100	78.14	16	0.061	62.834	100
7	2.510	51.610	82.83				

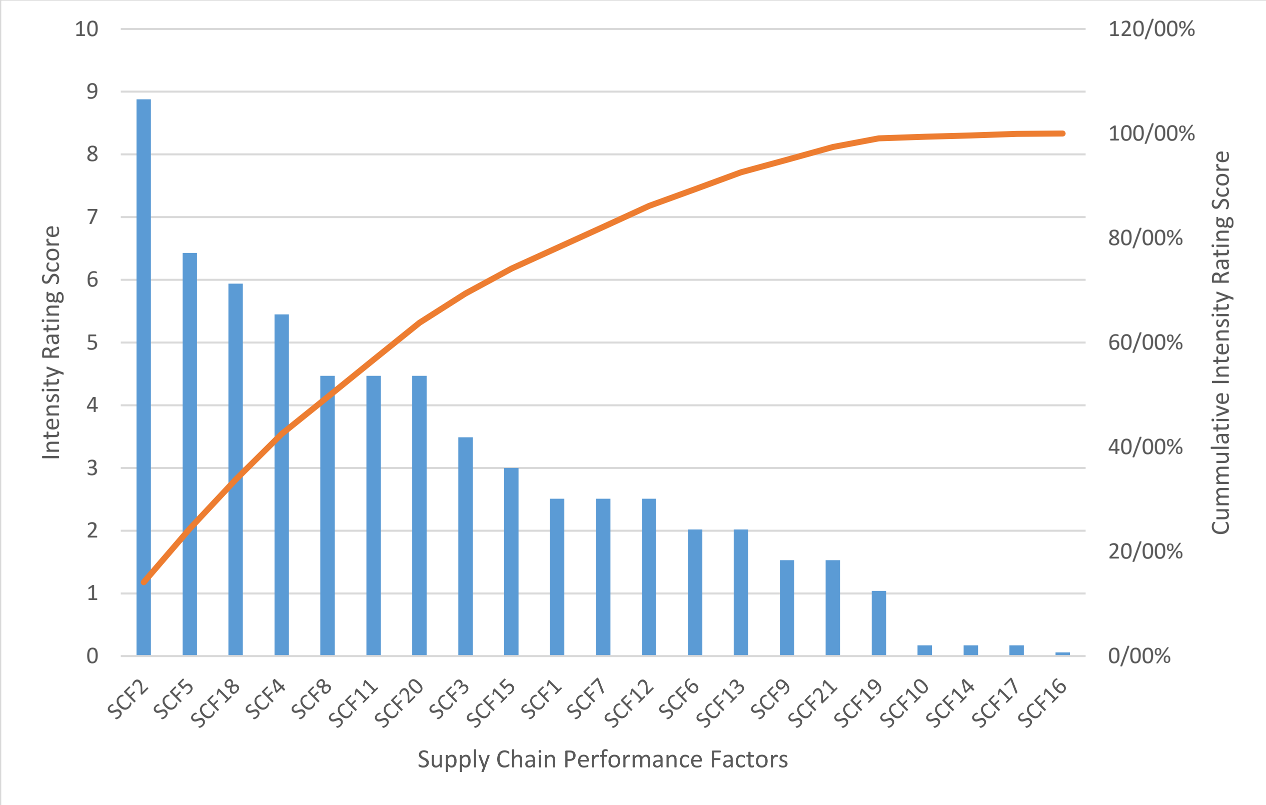

Figure 4. Pareto Chart of the Supply Chain Performance factors

Based on Table 4 and Figure 4, it could be inferred that an 82.83% supply chain performance threshold can be achieved in an organization that: (i) possess good leadership quality and top management support (factor 2), (ii) utilize suitable business strategies to minimize political and social risks associated with purchasing raw materials from overseas suppliers (factor 5) , (iii) that understand and accurately ascertain the customer demand pattern (factor 18), (iv) reforms and policies of the government favor smooth importing of raw materials from overseas suppliers (factor 4), (v) maintain a cordial relationship with its customers (factor 8), and (vi) effectively coordinate, control and manage supply chain activities (factor 11). In addition to this, the 82.83% supply chain performance threshold can be achieved in an organization that: (i) deploy a suitable forecasting method with a view to accurately predict customer demand (factor 20), (ii) that maintain a cordial relationship with its suppliers (factor 3), (iii) utilize suitable process strategies capable of meeting varieties of customer demand that fluctuate over time (factor 15), (iv) deploy suitable supply chain system configuration capable of meeting ever-changing customer demand and (v) maintain cordial relationship within the end-to-end processes of the supply chain of an organization (factor 7).

From this Pareto result, it could be inferred that supply chain managers and decision makers need to focus and concentrate their management efforts more on these aforementioned eleven (11) critical factors with a view to exponentially improve the performance of a supply chain system used in an organisation.

5. Managerial implications

The prioritization computation results obtained from this study implies that all the factors discussed in this study, to some extent, influences the performance of a supply chain system used in an organization. In light of this, supply chain managers should pay more attention to the factors with higher supply chain performance driving factors in order to exponentially improve supply chain performance. This denotes that various initiatives needs to be put in place in an organization in order to sustain these high supply chain performance driving factors. The study of Mabrouk et al. (2020) supported the aforementioned assertion, indicating that supply chain performance factors with high driving power, whose performance influences the performance of a high number other factors, needs to be carefully managed by supply chain managers. In light of this, the prioritization solution obtained in this study offers supply chain decision makers and practitioners a strategic blueprint and direction to develop strategies and policies that will promote supply chain continuous performance improvement and sustainability. In addition to this, management commitment in-terms of developing initiatives that will stimulate effective monitoring, measurement, continuous improvement and sustainability of supply chain system, plays a key role in influencing the performance of other factors that affect the performance of a supply chain. Hence, top management and supply chain managers of an organization must dedicate themselves and provide adequate resources, coordination and control mechanisms that will stimulate continuous supply chain performance improvement.

6. Conclusion

In view of the enormous pressure on supply chain managers to improve the performance of their supply chain systems, many organizations are forced to explore grey and novel solutions that are tailored towards improving the performance of a supply chain system. In light of this, this research work proposed a HSIM, which prioritized myriads of supply chain performance factors using the principle of subordination embedded in the Hierarchical Factor Tree Structure Diagram, in conjunction with the Pareto technique. The results of the HSIM deduced that eleven (11) critical factors need to be continuously monitored and improved, with a view to holistically improve the supply chain performance of organization. The solution obtained from this study should attract the supply chain performance management community since it open up a relatively new area of supply chain performance factors prioritization investigation towards continuous supply chain performance improvement. Appraising the supply chain performance of an organization using the intensity rating score of each supply chain performance factor obtained from this study could be explored in future studies. This research study contribute to the existing literature by: (i) unveiling the various factors that can influence the supply chain performance across the SIPOC (Supplier-Inputs-Process-Outputs-Customers) cycle, (ii) using a prioritization methodology premised on the theory of subordination to generate the interactions and hierarchy that occurs among various supply chain performance factors, and (iii) grouping the factors with the highest supply chain performance driving factors in order to pinpoint the core supply chain performance factors. Future studies should focus on the development of a supply chain performance improvement fund allocation model, based on the intensity rating scores of the supply chain performance factors obtained in this study.

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