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A Causal Model of Supply Chain Performance of the Seaweed Industry in Davao Region, Philippines

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Abstract
The study aimed to establish causal relationships between exogenous variables on supply chain performance of the seaweed industry in Davao Region through a multivariate analysis approach known as structural equation modelling (SEM). Exogenous variables in the study include supply chain quality management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency. Specific issues that were unaccounted by the SEM were also culled out using in-depth interviews. The sequential explanatory mixed-methods research design involved the collection of primary data from *N*=163 seaweed farmers in Davao Region. Results revealed that supply chain quality management practices, flexibility, and responsiveness were assessed high while supply chain efficiency was found to be moderate. Seaweed farms were found to perform very highly. The four exogenous variables were found to significantly and positively correlate with supply chain performance. In addition, results from the structural equation modelling revealed that the most suitable exogenous variables that best influence supply chain performance of seaweed farms in the Region are the supply chain's quality management practices and efficiency. The best-fitting structural equation model was able to satisfy most of the fit indices with exception to its SRMR and PNFI values.

Keywords
Agribusiness, Supply chain quality, Supply chain flexibility, Supply chain responsiveness, Supply chain efficiency, Supply chain performance, Seaweed farmers, Structural equation modelling, Philippines

INTRODUCTION
The seaweed sector is significantly impacted by supply chain management. The successful commercial manufacturing of seaweed is anticipated to yield substantial profits in today's competitive market. However, the main obstacle comes in the complex process of managing uncertainties across different locations within the seaweed supply chain network (Jindal, Sharma & Routroy, 2022). In the Philippines, the seaweed business is primarily controlled by autonomous producers who would likely gain the most by establishing strong collaborations with a wholesaler/distributor (Fabinyi et al., 2022; Engle et al., 2018; McHugh, 2006). Hence, it is imperative to build a cooperative management connection among supply chain partners in order to enhance integration and performance (Tsanos, Zografos & Harrison, 2014).

Furthermore, as a result of swift industrial progress, it is imperative for every company organization to augment their competitive edge to guarantee the uninterrupted continuation of their operations (Linda et al., 2022). The reason for this is that supply chain competitiveness is regarded as a strategy to deliver value to customers and achieve a competitive advantage (Mukhtar, 2015). In the current dynamic business environment, the capacity to provide excellent service is essential for the survival and prosperity of manufacturing and service activities. Consequently, the focus of competition is transitioning from individual firms to supply networks. In response to this change, companies are adopting supply chain management strategies to improve their ability to react promptly (Sarpong, 2022).

Moreover, contemporary business methodologies give utmost importance to the requirements and inclinations of consumers. Organizations are required to fulfill the individual demands of their clientele, which results in a concentration on improving flexibility. Organizations can effectively respond to the dynamic market situations by utilizing this capability (Harsasi, 2017). Flexibility is a powerful tool for improving the efficiency and quality of supply chain operations (Tiwari, Tiwari, & Samuel, 2015). Furthermore, given the market's dynamism, any departure in the quality of the final product is deemed unacceptable. Hence, it is imperative to evaluate quality management concerns in both inter-organizational and intra-organizational supply chain contexts (Sharma & Bhat, 2012).

Crucial elements that significantly improve supply chain efficiency encompass the proficiency and credentials of personnel, advancements in technology, programs for training and development, integration of company operations, and the construction of productive supplier partnerships. Farmers often aim to maximize their production of dried seaweed, which they sell to minor collectors or sea agents. These collectors are responsible for gathering and assessing the quality of the dried seaweed on the small sea platforms owned by individual farmers, which are distributed around the sea. Additionally, the moisture content (MC) is a crucial factor in determining the quality of dried seaweed, with a baseline range of 35% to 40%. If the market concentration (MC) exceeds 40%, the agent will propose a reduced price (Mansor, et al. 2020). Particularly, if a major corporation dominates one or several stages of the supply chain, it can exercise influence over pricing, quantities purchased, or quality attributes (Engle et al., 2018). On the other hand, these challenges related to supply chain efficiency are worsened by factors such as limited financial resources, reluctance to embrace change, absence of advanced technology, inadequate employee skills and qualifications, and lack of motivation (Fawcett, Magnan & McCarter, 2008; Kaur et al., 2024; Rizos et al., 2016).

Notably, a firm's competitive advantage varies significantly based on factors such as price (Huang et al., 2015), delivery dependability (Thatte & Agrawal, 2017), product innovation, and low time to market (Datar et al., 1997). In addition, a study also revealed that the level of operations system responsiveness has a direct impact on the firm's competitive advantage (Al-Hawajreh & Attiany, 2014). Specifically, emphasis was made on having a higher level of operations system responsiveness leading to a higher level of competitive advantage for the firm. This means that the level of responsiveness has a substantial influence on the performance of a service. It is found that there is a positive and significant correlation between the responsiveness of the operational system, logistics processes, and supply network (Al-Hawajreh & Attiany, 2014). Consequently, it is recommended that companies prioritize the pursuit of supply chain responsiveness throughout the entire process (Sarpong, 2022).

Supply chain integration enhances corporate performance by fostering innovation, enhancing supply chain flexibility, and bolstering supply chain resilience (Siagian, Tarigan & Jie, 2021). Supply chain management's flexibility and reactivity can improve the operational efficacy of the supply chain, as demonstrated by supply chain efficiency metrics (Negi, 2020). Additionally, the effective supply chain provides notable benefits by improving decision-making processes. The influence of flexibility and responsiveness on supply chain performance is deemed significant and cannot be overlooked (Sumardi et al., 2017). Thus, a pertinent assessment of performance shall require checking these factors, as they are vital for efficiently overseeing a supply chain (Nikfarjam et al., 2015). These may stem from manufacturing flexibility, which refers to the capacity to produce a diverse range of products efficiently and cost-effectively (Goldsby & García-Dastugue, 2003), further resulting in enhanced financial outcomes.

Seaweeds consistently ranks as one of the top three exports of the fisheries sector in the Philippines. However, a lot of challenges and uncertainties beset the industry. Uncertainties such as environment-related risks (e.g. disease, pest infestations) which, if unmanaged, could result to production failure (Suyo et al., 2021), and challenged affecting yield, quality, price, and infrastructure (Mulyati & Geldermann, 2017). These risks must be given more attention to increase the resilience of the supply chain (Mahmud & Kamarulzaman, 2020) as the supply chain's purpose is to satisfy the customer needs (Sumardi et al., 2017).

In Mindanao, the status of seaweed farming reveals its potential for economic growth, especially among small-scale farmers. However, despite the economic opportunities, a significant efficiency gap exists with the potential to reduce input usage by 55% to achieve equivalent output levels (Tahiluddin et al., 2023). The efficiency gap is evident in Davao Region as the seaweed industry is small, underdeveloped and fragmented. As a small industry, the type of seaweed production is technically inefficient, has poor logistics management, is economically disadvantaged, and environmentally vulnerable which limits its growth (Hurtado, 2013). Inefficiency is manifested by low yield, poor logistic management from selection of planting materials to marketing as result of fragmented system (Mulyati & Geldermann 2017), limited financial resources to innovate products from the producers' level (Soethoudt, Axmann & Kok, 2022; Songwe et al., 2016), and the seaweed growing is highly affected by climate change leading to vulnerability to environmentally-mediated diseases such as "*ice-ice*" (Peters, 2015; Qiu, 2017). These inefficiencies impede the sector's capacity to contribute to rural poverty reduction and sustainable development. This means that for Davao Region to be considered as key player in the Philippine seaweed industry, there is a need to developed conceptual model that will provide insight into how the integration of critical operational contingencies – such as information integration coordination of operational decisions – can help achieve superior performance across the supply chain (Tsanos & Zografos, 2016), coupled with a high level of trust and commitment in supply chain relationships (Chen, Wang & Yen, 2014).

With the abovementioned contexts and situations, this study is intended to determine the best causal model for the supply chain management performance of the seaweed industry in the Davao Region. Specifically, the study aims: 1) to assess the level of quality aspect in terms of internal management practices, upstream management practices, downstream management practices, quality performance, cost performance, and delivery performance; 2) to ascertain the level of flexibility aspect in terms of supply flexibility, product development flexibility, and production flexibility; 3) to find out the level of responsiveness aspect in terms of operation system responsiveness, logistics process responsiveness, and supplier network responsiveness; 4) to evaluate the level of efficiency aspect in terms of delivery, lead time, inventory turnover, internal performance, and service grade; 5) to determine the significant relationship between the exogenous variables (supply chain quality management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency) with supply chain performance; 6) to establish if exogenous variables (supply chain quality management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency) significantly influence overall supply chain performance of the seaweed industry in the Region; and 7) to derive the causal (structural) model that best characterizes the interrelationship of the variables.

METHOD

Research Design

The research designs suitable for quantitative approaches included descriptive survey, correlational, experimental, single-subject, and causal-comparative research methods (Lodico, Spaulding, & Voegtle, 2010). Correlational studies aim to determine if there are differences in the characteristics of a population depending on whether or not its subjects have been exposed to an event of interest in the naturalistic setting (Lau, 2017). The correlational method describes the relationship between the supply chain management aspects and customer satisfaction scores. According to Ellis-Jacobs (2011), this is appropriate as the study will identify the relationships between the mentioned variables.

Descriptive research design provides a detailed and accurate representation of the data collected, which can help generate hypotheses, explore trends, and identify patterns in the data (Dubé & Paré, 2003). The study, however, used the explanatory approach to investigate the relationship between the constructs. Explanatory designs give an account of why an event or phenomenon looks, changes, or varies in a research environment. Explanatory designs provide a complete and comprehensive understanding of the research problem (Toyon, 2021).

Respondents

The research study area encompassed the entirety of the Davao Region, including all regions where seaweed farms are situated. Given the extensive geographical coverage, it was feasible to conduct a thorough evaluation of the supply chain management performance in the seaweed industry. This ensured that the conclusions and insights accurately captured the diverse dynamics and challenges encountered by seaweed farmers, companies, and stakeholders in the scenic Davao Region. The research employed purposive sampling to meticulously select participants who were highly relevant to the study's objectives and adhered to established criteria. The sample size consisted of 163 individuals, comprising independent farmers, group members, and group leaders. The study's conclusions were bolstered by the extensive analysis of many perspectives and opinions, which contributed to a more thorough understanding of the research subject.

The research population consisted of all active seaweed farms, including grower group organizations, traders, trader-processors, and processors found within the Davao Region. Seaweed farmers can achieve concrete benefits that enhance their economic viability, competitive position in the market, and overall environmental sustainability (Vibe, 2020). The importance of these benefits cannot be overstated in ensuring the long-term viability and growth of seaweed farming enterprises. As a show of thanks for the participation in the study, a meaningful token of gratitude was given to all participants, including seaweed farmers, dealers, and processors. This gesture expresses gratitude for their excellent assistance and significant contributions to the study, acknowledging their crucial role in promoting research within the seaweed business.

Instruments/Measures

To measure the five variables, the study lifted different published scales from different studies. To measure supply chain quality management practices, the scale from Phan et al. (2019) was used, with six indicators: internal quality management, upstream quality management, downstream quality management, quality performance, cost performance, and delivery performance. To measure supply chain flexibility, the scale from Pujawan (2004) was adopted, with supply flexibility, product development flexibility, product flexibility, and delivery flexibility as indicators. To measure supply chain responsiveness, the scale was lifted and confirmed for completeness from three different sources (Sarpong 2022; Al-Hawajreh & Attianny, 2014; Thatte et al. 2013), with general responsiveness, operations system responsiveness, logistics process responsiveness, and supplier network responsiveness as indicators. Moreover, the scale of Pettersson (2008) was used to measure supply chain efficiency, which were assessed in the areas of delivery precision, lead time, cost, inventory turnover, internal performance, and service grade. Finally, to measure performance of the supply chain, the scale from several studies (Bielen & Demoulin, 2007; Sarpong, 2022; Um & Kim, 2019) was adopted. The indicators are as follows: service delivery performance, waiting time satisfaction, speed responding to changes, customized service. All were scaled using a five-point Likert type scale, where 5 means strongly agree and 1 means strongly disagree. As a guide in determining the level of the variables, the researchers used a scale, range of means, descriptive levels, and interpretations as presented below:

Scale	Range of Means	Descriptive Level	Interpretation
5	4.20 – 5.00	Very High	This means that the situation pertaining the variable is very high.
4	3.40 – 4.19	High	This means that the situation pertaining the variable is high.
3	2.60 – 3.39	Moderate	This means that the situation pertaining the variable is moderate.
2	1.80 – 2.59	Low	This means that the situation pertaining the variable is low.
1	1.00 – 1.79	Very Low	This means that the situation pertaining the variable is extremely low.

To ensure content validity of the scales to be used as in the survey questionnaire, six (6) experts were tapped to check the items' consistency, clarity, and adequacy. On the other hand, to ensure internal consistency of the items in the five variables, responses from a pilot test involving 15 seaweed farmers in Santa Cruz, Davao del Sur revealed good to excellent Cronbach's alpha and McDonald's omega values, which were all above 0.80.

Data Analysis

The data were encoded, tabulated, and further evaluated by using various statistical methodologies. Mean was used to evaluate and measure supply chain quality management practices, supply chain flexibility, supply chain responsiveness, supply chain efficiency, and supply chain performance. Pearson product moment correlation (Pearson *r*) was used in order to determine the correlation that exist between the four exogenous variables (supply chain quality management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency) and the endogenous variable (supply chain performance). The rating and interpretation were as follows: a rating of ±0.91 or higher indicates a strong correlation, a rating of ±0.61 to ±0.90 indicates a moderate correlation, a rating of ±0.31 to ±0.60 indicates a slight correlation, and a rating of ±0.00 to ±0.30 indicates a poor correlation.

Furthermore, multiple regression analysis was utilized in order to test if there are causal relationships that exist between the four exogenous variables (supply chain quality management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency) and the endogenous variable (supply chain performance). When they were established, the utilization of structural equation modelling (SEM) was necessary in order to determine the model that provided the best fit. All of the indices have to fall within the acceptable range in order to find the model that was considered as best-fit. To test the goodness of the fit of the model, the following standards were taken into consideration: a value greater than 0.95 for comparative fit index (CFI), Tucker-Lewis index (TLI), non-normed fit index (NNFI), relative noncentrality index (RNI), normed fit index (NFI), relative fit index (RFI), incremental fit index (IFI), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), and parsimony goodness of fit index (PGFI) (Cangur & Ercan, 2015; Gadelrab, 2005; Ramlall, 2016; Yaşlioğlu & Yaşlioğlu, 2020), a parsimony normed fit index (PNFI) close to 0.50 (Sahoo, 2019), an standardized root mean square residual value (SRMR) that is less than or equal to 0.08 (Shi, Maydeu-Olivares & DiStefano, 2018), a root mean square error of approximation (RMSEA) less than 0.06 with a non-significant p-value (RMSEA p or commonly referred as p of close fit) (MacCallum, Browne, & Sugawara, 1996), and lower values of ECVI and the information criteria AIC, BIC, and SABIC. All analysis of the dataset were performed in JAMOVI software.

Ethical Considerations

The study was conducted contingent to the approval of the University of Mindanao Ethics Review Committee (UMERC) dated February 17, 2024, with approval number 2024-029. All ethical standards were addressed before the administration of the survey.

RESULTS AND DISCUSSION

Supply Chain Quality Practice of Seaweed Farmers in Davao Region

Table 1 provides a detailed review of the methods used by farmers in the Davao Region to ensure the quality of the seaweed supply chain. With an overall mean score of 4.16 (SD=0.712), seaweed growers felt that quality was a factor to be taken into account and a measure of the Davao Region's seaweed industry's performance.

With very high ratings of 4.39 (*SD*=0.895), 4.35 (*SD*=0.837), and 4.20 (*SD*=0.724) for the top three performance indicators—delivery performance, quality performance, and internal quality management, respectively—seaweed farmers strongly agreed to consistently assure: (a) on-time delivery of orders to customers; (b) quality as the top priority to gain trust as product suppliers and involvement of customers regarding product quality improvement; and (c) provision of quality information giving emphasis to the organization's mission, goals, and strategies, dissemination and understanding in all units of the organization, and conduct of regular monitoring and updating.

The seaweed growers also decided that the remaining indicators—cost performance (m=4.03, *SD*=0.856), downstream quality management (m=4.01, *SD*=0.972), and upstream quality management (m=3.99, *SD*=0.988)—should be taken into account as supply chain quality practices in order to elevate the standing of the seaweed industry in the Davao region. The aforementioned metrics delineate the methodologies employed by seaweed farmers to achieve fair prices for goods and services between and among major participants in the supply chain (Muhtar & Makkalawu, 2023), both horizontal and vertical communication channels both inside and outside the seaweed farmers' organization (Zhang & Bakar, 2017), enduring partnerships with reliable suppliers (Duarte, Bruhn & Krause-Jensen, 2022), and the utilization of information technology to streamline transactions between suppliers and seaweed growers (Teniwut, Marimin & Djatna, 2019).

Table 1 Descriptive summary for supply chain quality practices of seaweed farmers

Item	Mean	SD	Descriptive Level
internal quality management	4.20	0.724	very high
upstream quality management	3.99	0.988	high
downstream quality management	4.01	0.972	high
quality performance	4.35	0.837	very high
cost performance	4.03	0.856	high
delivery performance	4.39	0.895	very high
Overall	**4.16**	**0.712**	**high**

Supply Chain Flexibility among Seaweed Farmers in Davao Region

Table 2 presents the average and standard deviation summary of the supply chain flexibility of seaweed growers in the Davao Region. The consolidated result indicates that seaweed farmers demonstrated a high level of flexibility in all the indicators considered, as evidenced by a mean score of 3.96 (*SD*=0.913). This flexibility suggests that seaweed farmers have the potential to become key players in the local, national, and global markets, thereby contributing to the significant growth of the seaweed industry in the Region.

Table 2 Descriptive summary for supply chain flexibility of seaweed farmers

Item	Mean	SD	Descriptive Level
supply flexibility	4.30	0.755	very high
product development flexibility	3.86	1.052	high
product flexibility	3.83	1.125	high
delivery flexibility	3.85	1.138	high
Overall	**3.96**	**0.913**	**high**

Specifically, seaweed farmers expressed a significant degree of flexibility across all four primary variables, with a high and very high level of rating. The supply flexibility of seaweed farmers was found to be exceptionally high, with a mean score of 4.30 (*SD*=0.755). This indicates that they effectively incorporate all the necessary elements of flexibility in their supply chain. These elements include having multiple qualified suppliers who can provide a variety of items required by the farmers at affordable prices, within a short timeframe, and with fast transportation and minimal additional costs (Christopher & Holweg, 2011; Stevenson & Pirog, 2008). The mean scores for product development flexibility (m=3.86, *SD*=1.052) indicate that seaweed farmers frequently engage in outsourcing, particularly for obtaining planting materials and other necessary inputs for establishing seaweed farms. This collaboration is typically done with government agencies that support the seaweed industry.

Additionally, the mean score for product flexibility is 3.82 (*SD*=1.125). The high score indicates strong support from local governments, as they issued concession agreements to seaweed farmers allowing them to establish farms in municipal waters. The seaweed farmers were highly skilled, having been exposed to various production and processing technologies provided by both local and national governments. Harvesting activities were carried out with the help of family members or skilled laborers hired from outside. The delivery flexibility score (m=3.85, *SD*=1.138) reflects the ease with which seaweed farmers can transport their products from the farm to collection sites, regardless of volume. This is made possible by each seaweed farmer owning a motorized banca, enabling quick and efficient delivery within a short period of time. Prospective purchasers personally retrieve the provided seaweed items within the agreed upon timeframe.

Succinctly put, the findings indicate that seaweed farmers' adoption of supply chain flexibility techniques aligns with the integration of important partners, serving as a crucial means to address organizational challenges and provide essential assistance to the seaweed industry in the Davao Region.

Supply Chain Responsiveness among Seaweed Farmers in Davao Region

The summary of supply chain responsiveness for seaweed producers, as presented in Table 3, demonstrates a high level of responsiveness, with an average value of 3.80 (*SD*=0.990). The seaweed farmers' affirmative agreement indicates that responsiveness is a key practice used by seaweed farmers to maintain the seaweed sector in the Davao Region.

Table 3 Descriptive summary for supply chain responsiveness of seaweed farmers

Item	Mean	SD	Descriptive Level
general responsiveness	3.80	1.135	high
operations system responsiveness	3.61	1.287	high
logistics process responsiveness	3.57	1.335	high
supplier network responsiveness	4.22	0.818	very high
Overall	**3.80**	**0.990**	**high**

As to indicators, general responsiveness of the supply chain was found to be high (m=3.80, *SD*=1.135). This is coupled with m=3.79 (*SD*=1.250) recorded for the seaweed farmers' responsiveness in their operations system. The average values indicate that seaweed farmers acknowledged the presence of operational system responsiveness in their organization. This includes the ability to quickly respond to changes in product volume demand, product mix demand, emergency customer orders, and the capacity to meet variations in demand (Angkiriwang, Pujawan & Santosa, 2014; Carvalho, Azevedo & Cruz-Machado, 2012; Morash, 2001). The mean values for logistic process responsiveness, with a mean rating of 3.57 (*SD*=1.335), indicate that seaweed farmers agree that they are capable of promptly responding to unexpected changes in demand. They are also able to adapt to the need for additional warehouse space and transportation to meet changes in demand, accommodate customer requests, and expedite delivery. The overall mean value of 4.22 (*SD*=0.818) indicates that seaweed farmers strongly agree that the supplier network is responsive. This means that the suppliers are able to make adjustments quickly when there are changes in volume or product mix. The farmers also appreciate when suppliers consistently accommodate their requests, provide efficient in-bound logistics, maintain a good on-time delivery record, and expedite emergency orders effectively. Overall, despite the intense rivalry in the seaweed market (Ushadevi & Burra, 2022; Stadenberg, 2016), seaweed farmers are able to effectively respond to consumer demand by promptly providing access to storage facilities and making changes to delivery schedules in a timely manner.

Supply Chain Efficiency among Seaweed Farmers in Davao Region

Table 4 displays the average and variability values of the six supply chain efficiency measures: delivery precision, lead time, cost, inventory turnover, internal performance, and service grade. The mean value for these metrics was 3.37 (*SD*=1.39). This indicates a relatively high level of efficiency. This suggests that the seaweed farmers did not prioritize efficiency, but rather focused on consistently meeting customer requirements (Wenäll & Leufstedt, 2023). This is also an indication that each individual seaweed farmer showed competence in managing projects or assignments within their designated responsibilities (Majid Cooke, 2004).

Table 4 Descriptive summary for supply chain efficiency of seaweed farmers

Item	Mean	SD	Descriptive Level
delivery precision	3.41	1.50	high
lead time	3.37	1.40	moderate
cost	3.33	1.42	moderate
inventory turnover	3.42	1.45	high
internal performance	3.35	1.41	moderate
service grade	3.30	1.50	moderate
Overall	**3.37**	**1.39**	**moderate**

The average values and standard deviations for all the supply chain efficiency techniques utilized by seaweed farmers indicated that delivery precision had a mean rating of 3.41 (*SD*=1.50) and inventory turnover had a mean rating of 3.42 (*SD*=1.45), both of which were considered high. These recommendations indicate that in order to achieve efficiency, seaweed farmers should ensure that they are aware of the quantity demanded by customers and provide it on time (Radulovich et al. 2015). Additionally, the organization should undertake annual inventory checks to monitor their operations. Meanwhile, the indicators of lead time, cost, internal performance, and service grade showed moderate levels of efficiency, with mean values of 3.37 (*SD*=1.40), 3.33 (*SD*=1.42), 3.35 (*SD*=1.41), and 3.30 (*SD*=1.50), respectively. Seaweed farmers use these indicators to monitor the time it takes from accepting an order until completion, calculate the expenses involved such as distribution and capital costs, measure internal performance based on production yield, order entry time, and capacity utilization, and evaluate customer feedback.

Moderate results denoted that seaweed farmers exhibit within the bounds or limited ability in keeping track of time from order acceptance until finish, accounting the cost incurred example distribution and capital cost, quantifying internal performance through yield in production, ordering entry time and capacity utilization, and assessing customers' feedback. These measures were partially in agreement with Pettersson (2008) that supply chain efficiency measurement must focus on measurements of how efficient a supply chain is, how supply chain cost and performance towards a customer to give a good picture of the efficiency of a supply chain, measurement of supply chain cost and measure performance for a company, thus compliance to attain full efficiency of supply chain performance of seaweed farmers must be improved.

Supply Chain Performance of Seaweed Farmers in Davao Region

Table 5 presents the average and variability values of the descriptive summary for supply chain performance measures of seaweed farmers. These metrics include service delivery performance, waiting time satisfaction, speed of responding to change, and service customization. The average value of 4.36 (*SD*=0.762) indicates a high level of agreement among seaweed growers about all aspects of supply chain performance. Moreover, the responses had a narrow dispersion from the mean, suggesting that seaweed farmers consistently operate at a level that exceeds expectations in delivering their services and meeting the demands of their clients.

Table 5 Descriptive summary for supply chain performance of seaweed farmers

Item	Mean	SD	Descriptive Level
service delivery performance	4.41	0.783	very high
waiting time satisfaction	4.31	0.853	very high
speed responding to changes	4.34	0.853	very high
customized service	4.39	0.890	very high
Overall	**4.36**	**0.762**	**very high**

The service delivery performance, with a mean value of 4.41 (*SD*=0.783), indicates that the respondents were highly confident in achieving a shorter throughput time, from the start of a given client service to its completion. Moreover, the seaweed farmers' responses regarding their satisfaction with waiting time also showed a mean value of 4.31 (*SD*=0.853). This indicates that the frequency of waiting in queues during service delivery has decreased, and satisfactory waiting time is provided in a satisfactory waiting environment. The speed of response, with a mean value of 4.34 (*SD*=0.853), indicates that seaweed farmers possess the capability to make desired adjustments in order to meet customers' requests. This is achieved by actively monitoring feedback and ensuring customer satisfaction through timely communication of changes and addressing any potential delays (Haimbala, 2019; Sandåker, 2018). Lastly, the customized service, which has a mean value of 4.39 (*SD*=0.890), demonstrates the seaweed farmers' capacity to offer personalized service that caters to the individual and unique requirements of their consumers. The results signify the gradual advancements made by the seaweed farmers in their supply chains.

Significance of the Relationship between the Exogenous Variables and the Endogenous Variable

On the relationship between supply chain quality management practices and performance

As reported in Table 6, the correlation matrix revealed that supply chain quality management practices (SCQMP) significantly and positively correlated with all indicators of supply chain performance (SCP) of seaweed farmers. Overall analysis reflected a positive and strong correlation (r=0.748, p<0.01) between supply chain quality management practices and supply chain performance. These indicated that all supply chain quality management practices employed by seaweed farmers lead to the enhancement of the performance of the seaweed farmers' organizations.

Table 6 Correlation matrix for supply chain quality management practices and supply chain performance of seaweed farmers

	service delivery performance	waiting time satisfaction	speed responding to changes	customized services	Overall
internal quality management	.560** (.000)	.615** (.000)	.562** (.000)	.543** (.000)	.632** (.000)
upstream quality management	.474** (.000)	.471** (.000)	.428** (.000)	.436** (.000)	.501** (.000)
downstream quality management	.541** (.000)	.488** (.000)	.470** (.000)	.430** (.000)	.533** (.000)
quality performance	.688** (.000)	.681** (.000)	.755** (.000)	.719** (.000)	.788** (.000)
cost performance	.481** (.000)	.419** (.000)	.414** (.000)	.407** (.000)	.475** (.000)
delivery performance	.642** (.000)	.616** (.000)	.719** (.000)	.679** (.000)	.736** (.000)
Overall	**.693** (.000)**	**.670** (.000)**	**.683** (.000)**	**.655** (.000)**	**.748** (.000)**

Looking at the pairwise correlation values, supply chain quality management practices highly correlated with supply chain performance indicators waiting time satisfaction (r=0.681, *p*<0.01), service delivery performance (r=0.688, *p*<0.01), customized services (r=0.719, *p*<0.01), and speed responding to changes (r=0.755, *p*<0.01). Results revealed that supply chain performance indicators lead the way for seaweed growers be more committed to focus primarily on quality performance as a vital factor to improve the service rendered to customers, waiting time period, ability to make desirable changes to meet customers request and customized service tailored meet specific and special needs of customers.

In addition, delivery performance registered strong positive correlation to service delivery performance (r=0.642, p<0.01), waiting time satisfaction (r=0.616, p<0.01), speed responding to changes (r=0.719, p<0.01), and customized services (r=0.679, p<0.01). Results suggested that commitment of seaweed growers to always be on time to deliver goods and services as required by customers significantly served as gauge to seaweed farmers to exercise higher level of improvement in the waiting time period of customers and service delivery performance, to be fast in responding to changes, and extend customized service.

The positive and strong correlation of the internal quality management practices was noted to service delivery performance (r=0.560, p<0.01), waiting time satisfaction (r=0.615, p<0.01), speed responding to changes (r=0.562, p<0.01), and customized services (r=0.543, p<0.01). These denoted that the seaweed farmers' practices on cascading quality management responsibilities to all members, keep members be knowledgeable of the goals, mission and strategies of the organization, provide an internal communication system, involvement of all members of the organization in identifying new products to be develop and solve problems that may occur and train new members steers seaweed farmers to continuously improve to customer retention and satisfaction.

In the same manner, the application of the upstream and downstream quality management practices by the seaweed farmers were positively correlated to supply chain performance measures on service delivery performance, waiting time satisfaction, speed responding to changes, and customized services. The overall analysis for the upstream and downstream quality management practices, r=0.501 (p<0.01) and r=0.533 (p<0.01), respectively demonstrated a strong and closely knit relationships with the customers and suppliers.

The weakest but positive correlation was observed on cost performance vis-a-vis the supply chain performance in terms of service delivery performance (r=0.481, p<0.01), waiting time satisfaction (r=0.419, p<0.01), speed responding to changes (r=0.414, p<0.01), and customized services (r=0.407, p<0.01). Results convey that price was the most important criterion that customers use to choose the organization as supplier however price cut or cost reduction effort were discussed with customers thus strengthening the service delivery performance, waiting time satisfaction, speed responding to changes, and customized services leading to continuous advancement of the seaweed farmers.

The findings above support the argument that effective quality management practices throughout the supply chain positively impact performance outcomes. These results align with previous research emphasizing the importance of quality management practices in enhancing supply chain performance (e.g., Mulyati & Geldermann, 2017; Soares, Soltani & Liao, 2017; Wright, 2017; Zeng, Phan & Matsui, 2013). Additionally, the significant positive correlation between overall supply chain quality management practices and overall supply chain performance underscores the holistic nature of quality management's influence on supply chain outcomes. Overall, these findings highlight the critical role of supply chain quality management practices in driving superior performance outcomes for seaweed farmers, emphasizing the importance of investing in quality management initiatives throughout the supply chain.

On the relationship between supply chain flexibility and performance

The evaluation of the correlation between the flexibility of seaweed farmers in terms of supply chain flexibility and the performance of their supply chain is presented in Table 7. The analysis of the results confirmed a substantial and robust link between the use of flexibility practices by seaweed farmers and the enhancement of performance in seaweed organizations in the Davao Region.

Table 7 Correlation matrix for supply chain quality flexibility and supply chain performance of seaweed farmers

	service delivery performance	**waiting time satisfaction**	**speed responding to changes**	**customized services**	**Overall**
supply flexibility	.437** (.000)	.459** (.000)	.528** (.000)	.514** (.000)	.539** (.000)
product development flexibility	.537** (.000)	.504** (.000)	.460** (.000)	.459** (.000)	.542** (.000)
product flexibility	.467** (.000)	.419** (.000)	.405** (.000)	.362** (.000)	.456** (.000)
delivery flexibility	.479** (.000)	.451** (.000)	.384** (.000)	.347** (.000)	.458** (.000)
Overall	**.538** (.000)**	**.510** (.000)**	**.486** (.000)**	**.458** (.000)**	**.551** (.000)**

The implementation of supply chain quality management practices, specifically those related to product development flexibility, supply flexibility, delivery flexibility, and production flexibility, showed a strong positive correlation with all indicators of supply chain performance. These indicators include service delivery performance ($r=0.538$, $p<0.01$), waiting time satisfaction ($r=0.510$, $p<0.01$), speed in responding to changes ($r=0.486$, $p<0.01$), and customized service ($r=0.458$, $p<0.01$). The analysis of the results showed that seaweed farmers' ability to outsource, collaborate with suppliers, provide transportation services, and employ skilled personnel for product development significantly enhances their experience and enables them to consistently maintain supply chain performance.

Overall, the analysis revealed a strong positive correlation ($r=0.551$, $p<0.01$) between supply chain flexibility management practices and supply chain performance indicators. This suggests that seaweed farmers in the Davao Region have successfully adapted, comprehended, and continuously enhanced their practices in the seaweed farming business, leading to improvements in the performance of the seaweed industry in the region.

The results suggest that improving flexibility in the supply chain has a positive effect on performance outcomes, enabling better adaptability to customer demands and market changes (Huo, Gu & Wang, 2018). This is consistent with previous studies (e.g., Ababouch et al. 2023; Naylor et al., 2021; Peschko, 2021) that highlights the significance of supply chain flexibility in attaining a competitive edge and enhancing overall performance. The strong positive correlation coefficients between the overall quality flexibility of the supply chain and the overall performance of the supply chain emphasize the broad impact of flexibility on different performance measures, emphasizing the strategic significance of promoting flexibility within the supply chain of seaweed farmers (Fayezi, Zutshi & O'Loughlin, 2017; van den Burg, Dagevos & Helmes, 2021; Wu & Pagell, 2011).

On the relationship between supply chain responsiveness and performance

The correlation analysis between supply chain quality responsiveness and supply chain performance of seaweed farmers is presented in Table 8. A number of significant correlations were observed in all indicators. A strong and positive correlation was registered between supply network and supply chain performance of seaweed farmers: service delivery performance ($r=0.725$, $p<0.01$), waiting time satisfaction ($r=0.700$, $p<0.01$), speed responding to changes ($r=0.769$, $p<0.01$), and customized services ($r=0.753$, $p<0.01$). These implied that a higher level of supply network responsiveness is associated with increased or higher level of performance among seaweed organizations in Davao Region.

In addition, the operation system responsiveness although weaker still displayed significant correlation to supply chain performance with coefficient correlation of $r=0.530$ ($p<0.01$) for service delivery performance, $r=0.464$ ($p<0.01$) for waiting time satisfaction, $r=0.385$ ($p<0.01$), speed responding to changes and $r=0.484$ ($p<0.01$) for customized services. Results meant that the significant operation system responsiveness initiates higher level of performance for seaweed farmers.

Table 8 Correlation matrix for supply chain responsiveness and supply chain performance of seaweed farmers

	service delivery performance	waiting time satisfaction	speed responding to changes	customized services	Overall
responsiveness	.530** (.000)	.464** (.000)	.385** (.000)	.376** (.000)	.484** (.000)
operations system	.406** (.000)	.430** (.000)	.360** (.000)	.346** (.000)	.426** (.000)
logistics process	.307** (.000)	.336** (.000)	.269** (.000)	.244** (.000)	.319** (.000)
supplier network	.725** (.000)	.700** (.000)	.769** (.000)	.753** (.000)	.817** (.000)
Overall	**.533** (.000)**	**.526** (.000)**	**.475** (.000)**	**.456** (.000)**	**.550** (.000)**

Logistics process responsiveness staged the weakest correlation to supply chain performance but still was noted to be significantly correlated to supply chain performance indicators: service delivery performance (r=0.307, p<0.01), waiting time satisfaction (r=0.336, p<0.01), speed responding to changes (r=0.269, p<0.01), and customized services (r=0.244, p<0.011) which directly also affects supply chain performance on a positive aspect.

Finally, the overall coefficient correlation r=0.550 (p<0.01) indicated that supply chain responsiveness plays a crucial function to improvement of the supply chain performance of seaweed farmers which eventually will contribute to the attainment of high performance of the seaweed industry in Davao Region. This implies that having a flexible and efficient operating system is crucial for improving various aspects of supply chain performance in the seaweed farming industry (Mathisen, 2018; Subramanian & Gunasekaran, 2015). Furthermore, the correlation coefficients indicate that supplier network responsiveness has the strongest association with all dimensions, emphasizing the crucial importance of strong and agile supplier networks in enhancing overall supply chain performance. These findings highlight the significance of investing in strategies that improve the ability of the supply chain to respond to quality issues, in order to enhance performance outcomes in the seaweed farming sector (Ababouch et al., 2023; Rimmer et al., 2021; Wright, 2017).

On the relationship between supply chain efficiency and performance

The correlation between the implementation of supply chain efficiency and the resulting supply chain performance measurements of seaweed growers in the Davao Region is displayed in Table 9. A strong correlation was found between lead time efficiency, cost efficiency, internal performance efficiency, and service grade efficiency, with overall coefficient correlations of r=0.214 (p<0.05), r=0.247 (p<0.05), r=0.210 (p<0.05), and r=0.232 (p<0.05), respectively. These correlations were observed in relation to supply chain performance measures, specifically service delivery performance, waiting time satisfaction, speed in responding to changes, and customized services. The findings revealed that the four specified supply chain efficiency methods had a substantial impact on enhancing the speed and accuracy of product delivery, reducing lead times, and improving customer satisfaction.

Table 9 Correlation matrix for supply chain quality efficiency and supply chain performance of seaweed farmers

	service delivery performance	waiting time satisfaction	speed responding to changes	customized services	Overall
delivery precision	.099 (.146)	.081 (.236)	.136* (.045)	.103 (.130)	.116 (.088)
lead time	.199** (.003)	.155* (.022)	.228** (.001)	.192** (.005)	.214** (.001)
cost	.240** (.000)	.168* (.013)	.263** (.000)	.221** (.001)	.247** (.000)
inventory turnover	.090 (.187)	.069 (.312)	.146* (.032)	.126 (.065)	.120 (.078)
internal performance	.191** (.005)	.139* (.041)	.225** (.001)	.204** (.003)	.210** (.002)
service grade	.222** (.001)	.151* (.026)	.255** (.000)	.210** (.002)	.232** (.001)
Overall	**.180** (.008)**	**.132 (.053)**	**.216** (.001)**	**.182** (.007)**	**.197** (.004)**

On the other hand, the analysis showed that there was no significant relationship between delivery precision (r=0.116, p=0.088) and inventory turnover (r=0.120, p=0.078) with overall supply chain performance. This suggests that the procedures used to measure these indicators do not have any impact on the improvement of supply chain performance for seaweed growers The correlation analysis investigates the association between the efficiency of supply chain quality and the performance of the supply chain in the seaweed farming industry. Notably, the results demonstrate different levels of correlation between various efficiency indicators and performance metrics. Lead time is strongly correlated with service delivery performance, waiting time satisfaction, and overall supply chain performance. This highlights the importance of reducing lead time to improve performance outcomes (Teniwut, 2020; Yong et al., 2022). Furthermore, there is a clear and consistent relationship between cost efficiency and performance across all dimensions. This indicates that supply chain operations that are cost-effective make a significant contribution to overall performance enhancements (Fatorachian & Kazemi, 2021; Soares, Soltani & Liao, 2017). These findings underscore the complex and diverse aspects of supply chain efficiency and stress the importance of comprehensive strategies to maximize efficiency and improve performance in the seaweed farming sector.

Structural Equation Modelling of the Variables

The causal modelling approach used in this study is model modification approach (Long 1983). Model modifications can be made based on substantive theory, using modification indices to identify which parameters should be freed until the model fits with the data, or Wald-based tests to determine which parameters should be fixed. Alternatively, a combination of these approaches can be used (Marcoulides & Falk, 2018).

Table 10 shows the model fit measures for Model 1. For one, the exogenous variables were found to have linear relationship with supply chain performance, $F(4, 212)=77.80$, $p<.001$. The variations explained by the four exogenous variables can be seen in the values of $R^2=0.595$ and $\Delta R^2=0.587$, wherein 58.7 to 59.5% of the variance of supply chain performance is explained by the combination of supply chain management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency of seaweed farmers.

Table 10 Model fit measures

Model	R	R^2	Adjusted R^2	AIC	BIC	Overall Model Test			
						F	df1	df2	p
1	0.771	0.595	0.587	313	333	77.8	4	212	< .001

To assess the individual influence of the exogenous variables towards the endogenous variable, multiple regression analysis was used to assess the combined influence of supply chain management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency of seaweed farmers on their supply chain performance. Conducting multiple regression analysis prior to structural equation modeling (SEM) can yield valuable insights into the connections between latent variables and their observed indicators (Kock & Lynn, 2012). This approach provides various advantages, such as verifying the measurement model, identifying potentially influential variables, and evaluating multicollinearity among predictors (Fornell & Larcker, 1981).

The results in Table 11 shows that supply chain quality management practices (QUALITY) has the highest beta coefficient (B=1.030, t=11.582, p<0.05), exhibiting a positive increase of 1.030 on supply chain performance in every one-unit mean increase/improvement of supply chain quality management practices. The coefficient estimate for the quality predictor is remarkably significant ($\beta = 0.963$, $p < .001$), indicating a robust positive correlation between supply chain quality and performance. This discovery highlights the crucial significance of quality management practices in improving different aspects of performance, such as service delivery, satisfaction with waiting time, and responsiveness (Alzoubi et al., 2022; Mitra, 2016; Zaid & Baig, 2020).

Table 11 Multiple linear regression model estimates

Predictor	B	SE	95% C.I.		t	p	B
			Lower	Upper			
(Intercept)	0.737	0.212	0.320	1.154	3.482	< .001	
Quality	1.030	0.089	0.855	1.206	11.582	< .001*	0.963
flexibility	-0.223	0.092	-0.405	-0.041	-2.411	0.017*	-0.267
response	-0.005	0.080	-0.162	0.153	-0.057	0.954	-0.006
efficiency	0.069	0.024	0.022	0.117	2.869	0.005*	0.126

Supply chain quality management practices was followed by supply chain flexibility (B=-0.223, t=-2.411, p<0.05), albeit posing negative beta coefficient, which translates that an increased flexibility of the supply chain of seaweed farmers in the Region by a unit mean increase would lead to decreasing performance of seaweed farmers by 0.223. This counterintuitive outcome may indicate possible difficulties linked to an excessive level of adaptability, such as heightened intricacy or reduced stability within the supply chain network (Aitken, Bozarth & Garn, 2016; Stevenson & Spring, 2007). Moreover, efficiency of the supply chain (B=0.069, t=2.869, p<0.05), posed a positive influence on performance, indicating a marginal 0.069-point increase on performance for every one-unit mean increase of the efficiency. However, supply chain responsiveness was found to have the least effect to supply chain performance (B=-0.005, t=-0.057, p=0.954). This means that a unit increase of this non-significant predictor has a rather small effect on performance, holding other variables constant, further emphasizing the significance of effective resource allocation and efficient procedures in enhancing performance in various aspects. Although it suggests that supply chain responsiveness may not have a substantial direct impact on overall performance in this particular situation, it is conceivable that its influence is moderated by other variables.

The variables were causally estimated in a structural equation modelling, wherein supply chain management practices, supply chain flexibility, supply chain responsiveness, and supply chain efficiency were tested for possible direct effects on supply chain performance. Figure 3 displayed the baseline model wherein the four exogenous variables were tested for direct effects (→) towards the endogenous variable while fundamentally co-variated (↔) among themselves. From the direct effects estimated in the structural equation model, results in Table 12 clearly indicates that the following paths are significant: quality to performance path (B=1.723), responsiveness to performance path (B=-0.499), and efficiency to performance path (B=0.064). On the other hand, the direct effect of responsiveness to performance (B=-0.369) was found to be non-significant. Consistent with the multiple regression analysis earlier estimated, we can see the dynamic interplay of the variables towards supply chain performance, in which increased levels of quality management and efficiency of the supply chain would lead to better performance while increasing responsiveness would lead to a decreased performance. To tackle these intricacies, it is important to implement specific interventions and continue conducting research. This will help in creating successful approaches to improve the performance of the supply chain and promote sustainable growth in the seaweed farming industry.

Table 12 Parameters estimates for the baseline model

Label	Endogenous	Exogenous	Estimate	SE	95% C.I.		β	z	p
					Lower	Upper			
p25	Performance	Quality	1.723	0.309	1.118	2.328	1.626	5.579	< .001
p26	Performance	Flexibility	-0.368	0.412	-1.175	0.439	-0.268	-0.893	0.372
p27	Performance	Responsiveness	-0.499	0.151	-0.794	-0.203	-0.796	-3.306	< .001
p28	Performance	Efficiency	0.064	0.026	0.013	0.116	0.143	2.464	0.014

On the other hand, the baseline structural equation model was tested for fit, i.e., ability of the model to be consistent with the dataset. Goodness-of-fit indices of the baseline model was reported in Table 13. The results of the tests conducted on the baseline model at a significance level of 5% indicate that the model failed to qualify the satisfactory values for a well-fitted SEM. Hence, the need to fit the model based on the goodness-of-fit indices needs to be done.

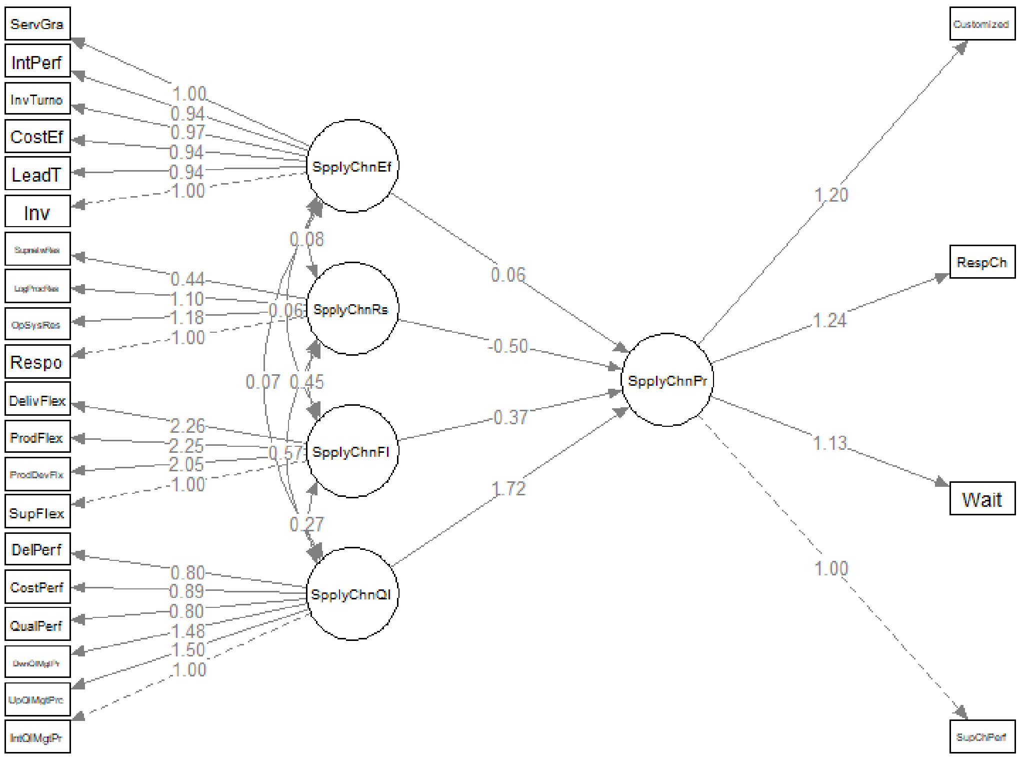

Fig. 1 Structural equation modelling results for the baseline model

Another consideration to improve to the fit of the model is to perform model modification (Kline 2018). There are two methods for modifying models in structural equation modeling: releasing constraints by adding free parameters and imposing constraints by eliminating free parameters. In this study, the modification process involved reduction of the sample size trimming the model by removing variables that have non-significant or problematic (i.e., multicollinearity) coefficients and eliminating responses through inspecting Mahalanobis distance (d^2), an approach suggested by scholars (e.g., Cilalı, 2015; Khamchan, 2018; Meade & Craig, 2012). In the modification process in this study, a total of 27 respondents were eliminated in the final dataset, as they contribute to the non-normality of the dataset, thereby making it less-fitting in the final estimation process (Foldnes & Grønneberg, 2022). In addition, the exogenous variables supply chain responsiveness and supply chain flexibility were eliminated.

Based on the improvements made on the baseline model, the parameters of supply chain responsiveness registered parameter values of its indicators above 0.90 while posing a direct effect of close to zero on supply chain performance, both indications of possible multicollinearity. Meanwhile, supply chain flexibility was eliminated due to a non-significant direct effect on supply chain performance. To further improve the goodness of fit of the model, an additional parameter was added, which is the direct effect of supply chain quality management practices on supply chain efficiency. This may indicate that there is an indirect effect in the model, such that a part of the total effect of supply chain management practices could pass through supply chain efficiency before directly affecting supply chain performance. In doing these modifications, the measures of goodness of fit in Table 13 showed significant improvements in the model. The comparison of model fit between the baseline and final models is documented in Table 13.

Table 13 Model fit comparison for all models generated

Measures of Fit	Standard	Baseline Model*	Final Model**
Standardized Root Mean Square Residual (SRMR)	≤ 0.08	0.122	0.092
Root Mean Square Error of Approximation (RMSEA)	≤ 0.06	0.151	0.057
RMSEA p (PCLOSE)	> 0.05	<.001	0.284
Comparative Fit Index (CFI)	≥ 0.95	0.832	0.999
Tucker-Lewis Index (TLI)	≥ 0.95	0.809	0.999
Bentler-Bonett Non-normed Fit Index (NNFI)	≥ 0.95	0.809	0.999
Relative Noncentrality Index (RNI)	≥ 0.95	0.832	0.999
Bentler-Bonett Normed Fit Index (NFI)	≥ 0.95	0.806	0.998
Bollen's Relative Fit Index (RFI)	≥ 0.95	0.779	0.997
Bollen's Incremental Fit Index (IFI)	≥ 0.95	0.833	0.999
Parsimony Normed Fit Index (PNFI)	Close to 0.50	0.707	0.691
Goodness of Fit Index (GFI)	≥ 0.95	0.9361	0.991
Adjusted Goodness of Fit Index (AGFI)	≥ 0.95	0.9145	0.983
Parsimony Goodness of Fit Index (PGFI)	Close to 0.50	0.6992	0.525
Expected Cross-Validation Index (ECVI)	Lower is better	7.4107	1.586
Akaike (AIC)	Lower is better	9415.0960	4553.163
Bayesian (BIC)	Lower is better	9692.2475	4726.413
Sample-size adjusted Bayesian (SABIC)	Lower is better	9432.3994	4549.125

* Baseline model in full dataset.

** Final model after re-specification and sample trimming based on Mahalanobis distance.

Compared to the baseline model, the final model has now achieved satisfactory values for various indices after the model respecification and modification process, which includes a value greater than 0.95 for comparative fit index (CFI), Tucker-Lewis index (TLI), non-normed fit index (NNFI), relative noncentrality index (RNI), normed fit index (NFI), relative fit index (RFI), incremental fit index (IFI), goodness of fit index (GFI), adjusted goodness of fit index (AGFI), and parsimony goodness of fit index (PGFI) (Cangur & Ercan, 2016; Gadelrab, 2005; Ramlall, 2016; Yaşlioğlu & Yaşlioğlu, 2020), a parsimony normed fit index (PNFI) close to 0.50 (Sahoo, 2019), an standardized root mean square residual value (SRMR) that is less than or equal to 0.08 (Shi, Maydeu-Olivares & DiStefano, 2018), a root mean square error of approximation (RMSEA) less than 0.06 with a non-significant *p*-value (RMSEA p or commonly referred as *p* of close fit) (MacCallum, Browne, & Sugawara, 1996), and lower values of ECVI and the information criteria AIC, BIC, and SABIC compared to the baseline model (Leppink, 2019). While the final model did not satisfy the SRMR and PNFI values, their final values were seen to be marginally close to the standard.

The final structural equation model in Figure 2 revealed that among the four exogenous variables, only the direct effects of supply chain quality management practices and supply chain efficiency on supply chain performance were retained to fit the model with the data. It can be concluded that both supply chain quality management practices (QUALITY) and supply chain efficiency (EFFICIENCY) play important roles in determining the supply chain performance (PERFORMANCE) of the supply chain among seaweed farmers in the Davao Region. However, QUALITY has a greater influence on performance compared to EFFICIENCY. This model highlights the significance of prioritizing both internal and external quality management practices and optimizing efficiency metrics such as lead time and inventory turnover to improve overall performance in the supply chain (Kimwaki, 2024; Rombe & Hadi, 2022). The inverse relationship between QUALITY and EFFICIENCY suggests that there may be complications in trying to maximize both aspects at the same time. This calls for additional research and careful planning to ensure that these factors are aligned effectively for optimal supply chain management.

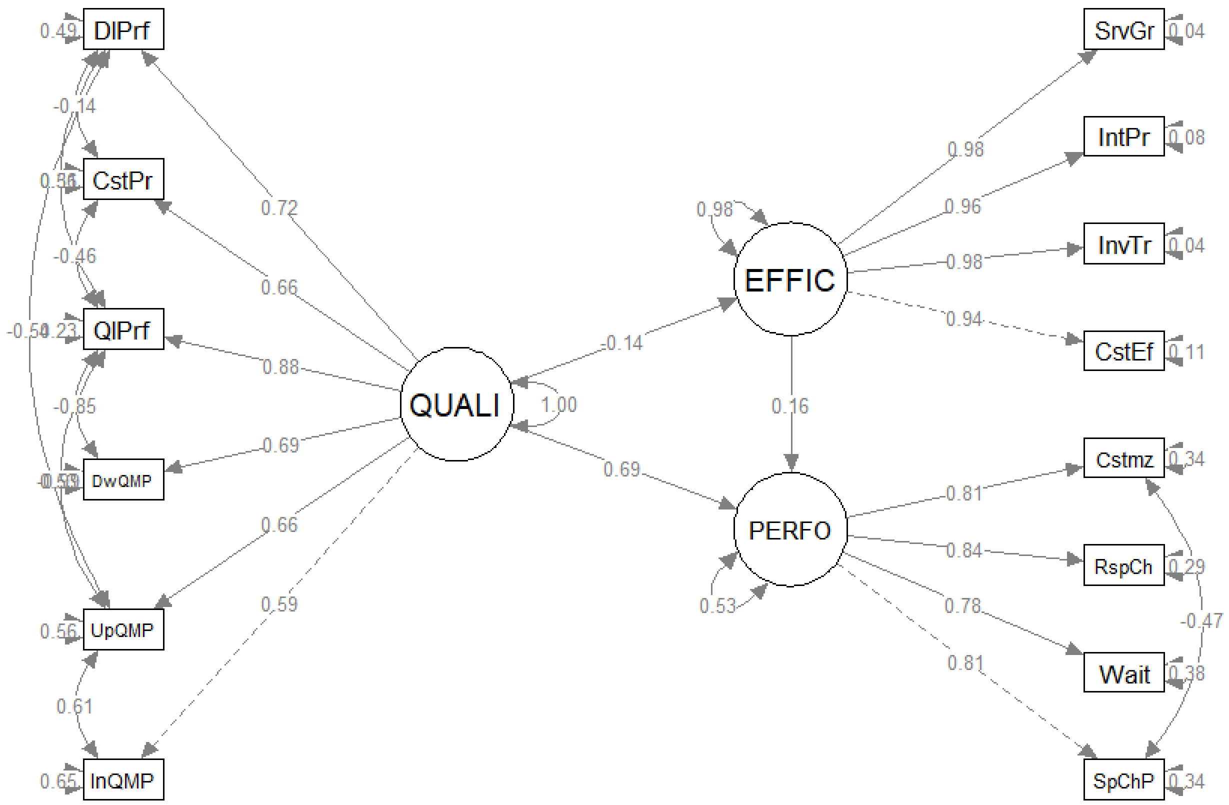

Fig. 2 Structural equation modelling results for the final model

LEGEND

Quali - Quality
DlPrf - Delivery Performance
CstPr - Cost Performance
QlPrf - Quality Performance
DwQMP - Downstream Internal Quality Management Practices
UpQMP - Upstream Internal Quality Management Practices
InQMP - Internal Quality Management Practices
Effic - Efficiency
Perfo - Performance
SrvGr - Service Grade
IntPr - Internal Performance
InvTr - Inventory Turnover
CstEf - Cost Efficiency
Cstmz - Service Customization
RspCh - Speed of Responding to Change
Wait - Waiting Time Satisfaction
SpChP - Supply Chain Performance (change to Service Delivery)

CONCLUSION

In the dynamic seaweed business environment in Davao Region, the overall observed valid and reliable measures for supply chain performance were quality and efficiency. The study highlighted the key roles of quality and efficiency practices as the most important variables to lead and keep the seaweed industry in Davao Region in the high level of competitive advantage among seaweed farmers in the country.

Moreover, although quality management practices employed by seaweed farmers emerged with the greatest influence affecting supply chain performance, there was negative interaction on the efficiency practices to quality practices as reflected in the final structural model. In effect, the empirical results revealed the capacity of the seaweed farmers to consistently assured an on-time delivery of orders to customers; maintain the gained trust as product suppliers and involvement of customers regarding product quality improvement; provision of quality information giving emphasis to the organization's mission, goals, and strategies, dissemination and understanding in all units of the organization, and conduct of regular monitoring and updating while efficiency falls directly to the seaweed farmers alone by integrating important partners/suppliers.

RECOMMENDATIONS

The study's findings indicate that the Davao region's seaweed business mainly comprises small and very small groups. These groups risk declining because larger companies that exploit marine resources are encroaching on their territory. In order to tackle this issue, it is crucial for both the government and business sectors to make joint and focused endeavors. Hence, it is imperative for supply chain participants, including wholesalers and retailers, to actively contribute to the promotion of sustainable practices and the support of local seaweed farmers by procuring their products and offering equitable market rates. These endeavors should encompass the development of policies to guarantee fair and just utilization of marine waters, the creation of nearby seaweed processing facilities to optimize supply chain operations and minimize transportation distances, and the allocation of financial assistance for the establishment and functioning of processing plants, in addition to comprehensive training and development initiatives for the workforce.

Moreover, creating a dedicated local processing facility exclusively for producing carrageenan has great potential, especially for exporting, considering the region's proximity to international sea and airports. Reducing the distance between fields and markets will be advantageous for seaweed growers and increase their involvement and influence in the supply chain. Seaweed farmers' associations must be actively engaged as crucial participants in the seaweed value chain roadmap, guaranteeing their involvement and participation in industry decisions and activities.

Extending the scope of technology business incubation programs, like the Davao del Sur State College Technology Business Incubation (DSSC-TBI) center, to other regions where seaweed cultivation is prevalent can act as a catalyst for rejuvenating the industry. It is essential to enhance the implementation of laws and regulations related to preserving the seaweed business at all levels of local government to secure its interests. Furthermore, promoting cooperation and disseminating knowledge among all parties involved through different channels, such as trainings, workshops and seminars, can enhance the sharing of successful methods and creative solutions, thus enhancing the overall efficiency of the seaweed supply chain.

Future researchers are advised to perform additional studies on the socio-economic consequences of different interventions in the seaweed business and investigate the potential of emerging technologies to improve production efficiency and product quality. Effective collaboration among all stakeholders, including prospective researchers, would be crucial in facilitating favorable transformation and guaranteeing the sustainable future of the seaweed business in the Davao region and beyond.

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