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Rice Distribution System Design with SCOR and System Dynamics Approach: A Case Study in Eastern Region of Indonesia

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Abstarct. This study analyzes the rice distribution system in East Indonesia using supply chain operations reference (SCOR) and system dynamics methodology. Performance of the supply chain is measured for 431 small and medium enterprises using SCOR metrics weighted by analytical hierarchy process. The overall performance is found to be good (82.85) but specific indicators related to production capacity, cost and sustainability need improvement. Additionally, a system dynamics model is developed to simulate optimal rice distribution patterns. The results indicate increasing planting area and productivity in Eastern provinces can enhance rice supply to meet household demand. The study provides practical guidance to improve rice supply chain efficiency and sustainability in Indonesia.

Keywords: Supply Chain, Rice Distribution, SCOR, AHP, System Dynamic

1. Introduction

In 2022, Indonesia's Global Food Security Index (GFSI) score increased to 60.2%, reflecting a significant improvement in food availability . However, beneath this improvement, complex challenges persist in rice distribution in the Eastern region of Indonesia (Sukereman et al., 2022). The rice supply chain in this area has not been comprehensively understood, and holistic solutions to this issue have yet to be provided in previous research. Prior studies have primarily focused on issue identification, lacking a comprehensive perspective on integrated solutions.

Rice, the subject of this research, serves as a staple for a substantial portion of the Asian population, including Indonesia. It plays a vital role in ensuring food security in the country as a staple food (Putra et al., 2021). In 2017, rice consumption per capita in Indonesia was recorded at nearly 150 kilograms per person per year (Aido et al., 2021).

In Indonesia, a significant imbalance in rice production between the western and eastern regions exists. The eastern part of Indonesia faces unique challenges in ensuring an adequate rice supply. The rice supply chain in this region needs strengthening to address production disparities and meet the growing demand for rice (Octania & Galuh, 2021; Pratama et al., 2019).

The term rice supply chain referred to here pertains to the physical network connecting companies involved in raw material supply, production, post-harvest, storage, processing, and distribution, along with the interconnections between these components (Radhi & Hariningsih, 2021). The food supply chain encompasses several stages related to supply, production, post-harvest, storage, processing, and distribution, along with the interrelations among these components (Behzadi et al., 2018).

Numerous studies have been conducted concerning supply chain and distribution aspects. Various studies have been carried out across Asian regions. (Syed et al., 2018) conducted research on the impact of food supply chain issues on malnutrition cases in multiple Asian countries, yielding broad policy recommendations for governments, food regulatory authorities, donor agencies, and non-governmental organizations to strengthen food supply chains and reduce malnutrition cases. Another study conducted by (Kunnapapdeelert & Pitchayadejanant, 2021) investigated the effects of supply chain strategies on integration and how supply chain integration influences operational performance in Thailand. The results demonstrated positive effects of various supply chain integration forms, with internal integration affecting operational performance.

In Indonesia, several studies related to supply chain management have also been produced. One such study conducted by (Kesy Garside et al., 2015) which simulated the rice supply system in East Java Province and recommended food security policies in Indonesia. Other research was also conducted by (Setiawan et al., 2020) which aims to see the extent of the transformation of supply and demand in Indonesia, the results show an imbalance between supply and demand. In the technology aspect there is the research by (Afrianto et al., 2020) which identified agro-industry supply chain problems and recommended the application of blockchain technology to address agro-industrial supply chain problems in Indonesia. And the last one is the research by (Defrizal et al., 2020) which discusses how the rice supply chain system in Aceh province.

Based on several previous studies, various challenges in the Indonesian food supply chain have been identified (Umaran et al., 2022). However, concrete benefits in addressing supply chain issues in the Eastern region of Indonesia, which also impact the GFSI score, have not been fully revealed. Hence, the purpose of this study is to identify distribution conditions and measure the performance of the rice supply chain in Eastern Indonesia, particularly in the provinces of Maluku, North Maluku, Papua, and West Papua. Furthermore, this study aims to optimize the rice supply chain system through dynamic system simulation. Research data was collected over a three-month period, from February to May 2023. This study employs a supply chain operational references combined with an analytical hierarchy process, alongside dynamic system simulation using the Vensim software. In this context, the study contributes to addressing crucial challenges in the rice supply chain in Eastern Indonesia, proposing a holistic and integrated approach.

2. Literature Review

The intricate dynamics within a supply chain are crucial determinants of food security levels in a specific region. This network of interconnected processes, often referred to as the supply chain, encompasses diverse activities involving the exchange of information, finances, and resources between suppliers and consumers (Trueba-Castañeda et al., 2022). This reality underscores the pivotal role played by supply chains in ensuring the availability and accessibility of essential goods, including food.

Furthermore, within the realm of supply chain dynamics, Supply Chain Management (SCM) is a critical discipline that governs the interactions from suppliers to customers, with the goal of optimizing factors such as reliability, agility, and responsiveness while minimizing costs and maximizing customer value (Asrol & Soinangun, 2022; Boateng, 2019). Particularly, the evolving landscape of SCM increasingly highlights sustainability issues, integrating social concerns and global climate change into its scope (Mageto, 2021). This evolution emphasizes the intricate interplay between supply chain dynamics and broader global challenges.

In addition to SCM, the Supply Chain Operations Reference (SCOR) model offers a standardized framework designed by the Supply Chain Council (SCC), as depicted in Figure 1 (Azmiyati & Hidayat, 2016).

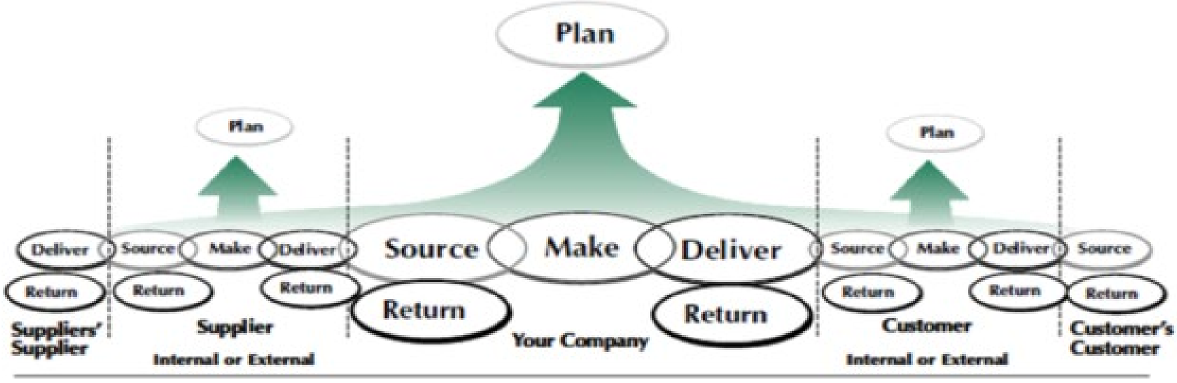

Fig. 1: SCOR Model (Source: Supply chain Council)

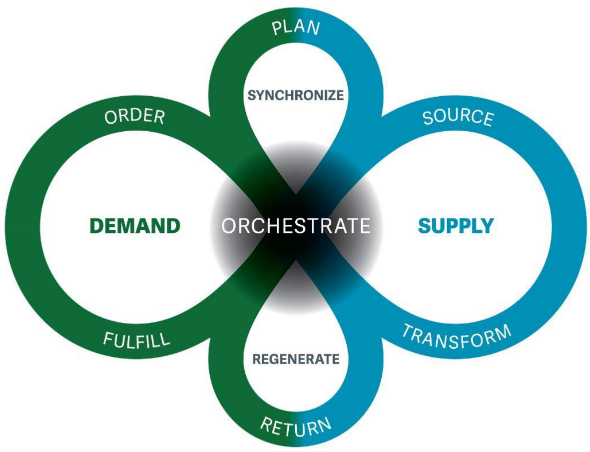

Fig. 2: SCOR-DS in the Seven Key Management Processes (Source: ASCM SCOR Model, 2022)

The SCOR model was created to describe the business operations involved in all stages of client request fulfillment, as depicted in Figure 2. SCOR serves as a key tool to enhance communication and coordination among supply chain stakeholders and streamline supply chain management. Furthermore, the recent development of the SCOR-DS (Digital Standard Supply Chain Operation Reference) by the Association for Supply Chain Management (ASCM) introduces methodologies, diagnostics, and benchmarks facilitating rapid organizational enhancements within supply chain processes (ASCM, 2022).

However, addressing the intricate dynamics of supply chains requires not only structured frameworks but also quantitative methodologies. The Analytic Hierarchy Process (AHP), introduced by Thomas Lorie Saaty, is one method that aids in evaluating complex situations through pairwise hierarchical comparisons (Wang et al., 2018). AHP's ability to rank options based on their alignment with primary objectives is highly valuable in supply chain analysis.

Moreover, assessing supply chain performance involves the use of performance metrics, with the AHP method serving as the basis for weighting these metrics. This process involves pairwise comparisons among various supply chain processes, often through questionnaire distribution (Sutoni et al., 2021). This performance measurement, based on standard scores and benchmarks, provides a structured approach to evaluate supply chain efficiency and effectiveness (Marimin et al., 2020).

Furthermore, dynamic system models offer innovative approaches to understand and manage complex systems such as supply chains. These systems, characterized by dependencies and feedback loops, are effectively analyzed through computer-assisted simulations (ASDI, 2020). The core of this approach lies in constructing causal loop diagrams, which illuminate complex causal relationships and form the basis for building System Dynamics models (Saeri et al., 2019).

This brings us to the integration of quantitative methods and dynamic system models. These models, composed of stocks and flows, capture variable interactions within dynamic systems. Cause-and-effect relationships, representing intricate causal dynamics, are translated into first-order differential equations and numerically solved using software like Vensim. As seen in Figure 3, the main elements of a System Dynamics model are stocks and flows. Stocks are the variables of interest whose dynamics we want to understand. Flows are the rate of change of stocks per unit of time (Gunawan, 2022). This holistic approach empowers decision-makers not only to understand but also to predict the behavior of complex systems, thereby enhancing supply chain management and its profound impact on food security.

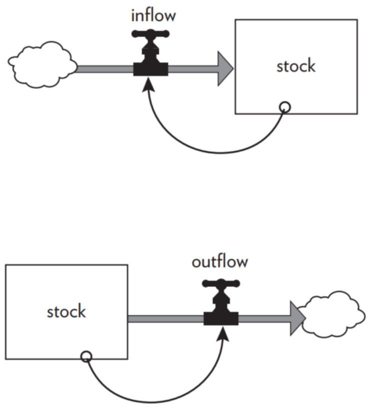

Fig. 3: Illustration of Two Types of Feedback Interactions Between Stocks and Flows (Meadows, 2008)

Although the Supply Chain Operations Reference (SCOR) model has served as a valuable framework for standardizing supply chain processes, its application might not comprehensively address the nuances of specific systems such as rice distribution. Similarly, the Analytic Hierarchy Process (AHP) methodology, although effective in prioritizing options, has been criticized for inherent subjectivity. Additionally, AHP might not fully depict the dynamic interactions occurring within complex supply chains, potentially limiting its effectiveness in addressing real-time challenges.

The collective limitations in existing literature underscore the need for research efforts to bridge these gaps by integrating performance measurement with rice distribution system optimization. This study aims to address these shortcomings by providing a comprehensive approach considering the dynamics of various aspects within the supply chain, leveraging the strengths of existing models, and filling the gaps left by their individual limitations. In doing so, this research aims to enhance the understanding of supply chain dynamics, provide new insights into performance optimization, and ultimately drive the goal of enhancing food security through efficient rice distribution.

3. Method

The focus of this research is the rice supply chain in Eastern Indonesia. Figure 4 shows the research stages.

3.1. Supply Chain Performance Measurement

Researchers used the SCOR model to assess the effectiveness of the rice supply chain in eastern Indonesia. The Supply Chain Council (SCC), a separate non-profit organization, created the conceptual model known as SCOR (Supply chain Operation Reference) as a standard for all industries. As a first step toward achieving an effective and efficient supply chain management that supports the company's goal, SCC's standardization efforts are intended to make it easier to comprehend the supply chain (Azmiyati & Hidayat, 2016).

This study uses the latest SCOR model developed by ASCM (Association for Supply Chain Management), namely SCOR-DS (Digital Standard Supply Chain Operation Reference) or SCOR Version 14.0. SCOR-DS is a model that provides methodologies, diagnostics, and benchmarks to help rapidly improve organizational performance in supply chain processes. The SCOR 14.0 process hierarchy consists of four levels.

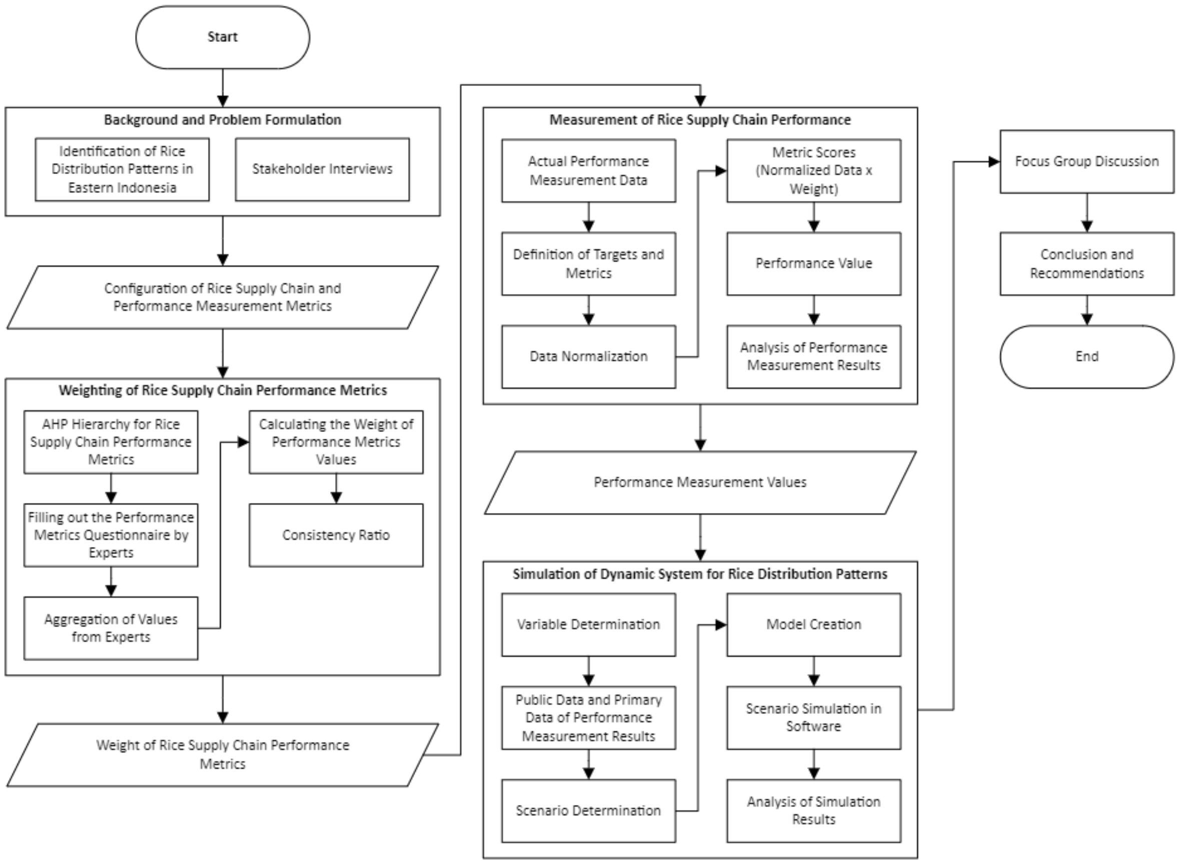

Fig. 4: Research Stages

3.2. Selection of Metrics for Supply Performance Measurement

Determination of performance metrics in this study refers to the SCOR 14.0 model and previous studies. Furthermore, the existing metrics are poured into a semi-closed questionnaire.

Retrieval of data using the snowball sampling method through questionnaires will then be translated in the form of a hierarchy, followed by giving weights or degrees of importance between each variable. This stage uses the Analytical Hierarchy Process (AHP) method.

3.3. Performance Measurement Metric Weighting with AHP Method

The AHP approach uses pairwise comparison metrics to organize criteria and options in a hierarchical structure, which helps to simplify complex and unstructured situations (Wang et al., 2018). Some pairwise comparison metrics used in the AHP model are based on the basic comparison scale's nine levels.

Pairwise comparisons among five experts and geometric mean aggregation are conducted using the following equation:

$$\bar{x}_{ij} = \sqrt[n]{\prod_{x=1}^{n} X_k} \qquad (1)$$

$$Y = X \times X \qquad (2)$$

$$W_{(Ii)} = V_{pi} = \frac{\sum_{j=1}^{J} Y_{ij}}{\sum_{i}^{I} \sum_{j=1}^{J} Y_{ij}} \qquad (3)$$

In the formula, the geometric mean for each metric in AHP is represented by $(\bar{x}_{ij})$, where X_k is the value provided by expert k for a total of n observations. Then, the metric X is multiplied by itself, resulting in a new metric Y. Vectors for each indicator are determined for performance measurement i, denoted as (V_{pi}). These values represent the priority weights of performance indicators i, symbolized as $W_{(Ii)}$. The values are formed by the summation of pairwise comparisons for row i and column j $(\sum_{j=1}^{J} Y_{ij})$, divided by the total metric for i, j $(\sum_{i}^{I}\sum_{j=1}^{J} Y_{ij})$.

To implement the paired comparison method as described, it requires competent experts with adequate capabilities. These experts use the purposive sampling method, where the selection objective for experts is individuals who possess competence in rice supply chain issues in Eastern Indonesia. The group of experts consists of five individuals from both government and private sectors. From the government sector, they include one expert from the Directorate General of Plantation, Ministry of Agriculture of the Republic of Indonesia, one director from a State-Owned Enterprise related to food, and a lecturer from one of the state universities in Eastern Indonesia. Meanwhile, from the private sector, there is a CEO from a national-scale retail business group and an owner of one of the rice mills in the Eastern Indonesia region that supplies rice to Eastern Indonesia. These experts represent stakeholders in the rice supply chain in the Eastern Indonesia region, ensuring that the results of the AHP can reflect the current conditions.

3.4. Model for Measuring Supply Chain Performance

The performance measurement of rice supply chain in East Indonesia is carried out using performance metrics adopted from SCOR version 14, year 2022. In addition to utilizing SCOR, the AHP method is employed to assess the level of importance.

This process begins with establishing standard scores and benchmarks for each performance metric $B(I_i)$, which facilitates the normalization process and calculation of performance scores for metric $I(i)$. Each metric also has a maximum target $(max(i))$ or minimum target $(min(i))$ based on the respective scores and dimensions of the metric.

Formulas 4 and 5 are utilized to normalize the values of each metric according to the pre-determined maximum or minimum targets. These values can be observed in formulas 6 and 7.

The maximum and minimum values are obtained from all the metric values of the supply chain (n), while the reference values for each indicator are derived from the best values $B(I_i)$ of each indicator on a monthly basis. This can be observed in formulas 8 and 9.

$$N(I_i) = \begin{cases} \dfrac{I_i - \min(i)}{B(I_i) - \min(i)}\ ; if\ I_i \le B(I_i) \\ 1\ ; if\ I_i \ge B(I_i) \end{cases} \tag{4}$$

$$N(I_i) = \begin{cases} 1\ ; if\ I_i \le B(I_i) \\ \dfrac{\max(i) - I_i}{\max(i) - B(I_i)}\ ; if\ I_i \ge B(I_i) \end{cases} \tag{5}$$

$$min\ (i) = \min\ (I_1, \dots, I_n) \tag{6}$$

$$\max(i) = \max\ (I_1, \dots, I_n) \tag{7}$$

$$B(I_i) = \max\ (I_i, \dots, I_j)\ , if\ Target = \max \tag{8}$$

$$B(I_i) = \min\ (I_i, \dots, I_j)\ , if\ Target = \min \tag{9}$$

The normalization process results in values for each metric within the interval [0,1]. Subsequently, the performance scores of each stakeholder are determined based on the importance level of each metric W(I(i)) and the normalized values of the metrics $N(I(i))$. The final score for the supply chain performance is obtained by summing up the weighted scores of all metrics (n) after multiplying the metric weights with the normalized metric performance scores, as seen in formula 10. The categories of supply chain performance calculation results can be seen in Table 1.

$$K_A = \sum_{i=1}^{n} W(I_i) \times N(I_i) \qquad (10)$$

Table 1. Supply Chain Performance Standart Score

Performance Score (%)	Criteria
85 - 100	Excellent
80 - 84	Good
70 - 79	Moderate
65 - 69	Poor
60 - 64	Very Poor
<60	Bad

3.5. Dynamic System Simulation

In general, the process of building an SD model can be described as follows. First, the model's objectives are clearly defined and articulated. Then, the system boundaries are determined. After that, the feedback loop diagram is drawn. Once the flow diagram is created, the numerical functions of the model are developed. These functions will be further developed for operational processes, calibration, and model evaluation. The final stage involves using the integrated model (Song et al., 2018).

Four integrative models that combine the distribution patterns of rice in the four provinces of Eastern Indonesia and rice production at the rice mills in South Sulawesi Province were constructed in this research. The rice supply in each province was chosen as the model boundary for this study. The integrated system simulation was carried out using Vensim PLE, a professional dynamic system software package. The simulations were conducted for five consecutive years from 2022 to 2027.

The relationship between measuring supply chain performance using the SCOR model and simulating rice distribution patterns using the dynamic system method is that the Key Performance Indicators (KPIs) utilized in measuring supply chain performance using the SCOR model are employed as variables in simulating rice distribution patterns using the dynamic system method. In this research, the values of several KPIs generated from measuring supply chain performance using the SCOR model are employed as variables in simulating rice distribution patterns using the dynamic system method. These KPIs include production capacity, human resource capacity, and energy consumption. This implies that these KPIs are used to model the behavior of the rice distribution system over time, and the simulation results can be utilized to optimize the performance of the system.

3.5.1. Simulation Variables

The variables in the simulation of rice supply chain in four provinces of East Indonesia refer to secondary data published by government institutions and direct observations in the field during the course of the research, as presented in Table 2.

Table 2. Simulation System Variables in the East Indonesia Rice Supply Chain

Variable	Initial Values of Maluku Province (unit)	Initial Values of North Maluku Province (unit)	Initial Values of West Papua Province (unit)	Initial Values of Papua Province (unit)	Source
The rice mill production in Sidrap Regency	484.82 (tons/year)	432.87 (tons/year)	432.87 (tons/year)	380.93 (tons/year)	Central Statistics Agency
Local rice production	65,000 (tons/year)	16,000 (tons/year)	16,000 (tons/year)	163,000 (tons/year)	Central Statistics Agency
Local distributor	17,192.30 (tons/year)	432.80 (tons/year)	432.90 (tons/year)	90,412.30 (tons/year)	Central Statistics Agency
Household rice consumption	60,025.80 (tons/year)	13,781.70 (tons/year)	11,292.10 (tons/year)	143,841 (tons/year)	Central Statistics Agency

Harvested land area	28,319.8 (ha)	7,781.96 (ha)	6,414.94 (ha)	64,984.90 (ha)	Ministry of Agriculture
Crop productivity	4.12 (tons/ha)	3.60 (tons/ha)	4.20 (tons/ha)	4.40 (tons/ha)	Ministry of Agriculture
Rice production yield presentation	55 (percent)	57 (percent)	60 (percent)	57 (percent)	Ministry of Agriculture

3.5.2. Dynamic System Simulation Model

In the development of the system model for the rice supply chain in East Indonesia, the Vensim software was used. This simulation model was constructed based on the observations made by the researchers during the field study and also referenced relevant literature. The following is the simulation model that has been built, as shown in Figure 5.

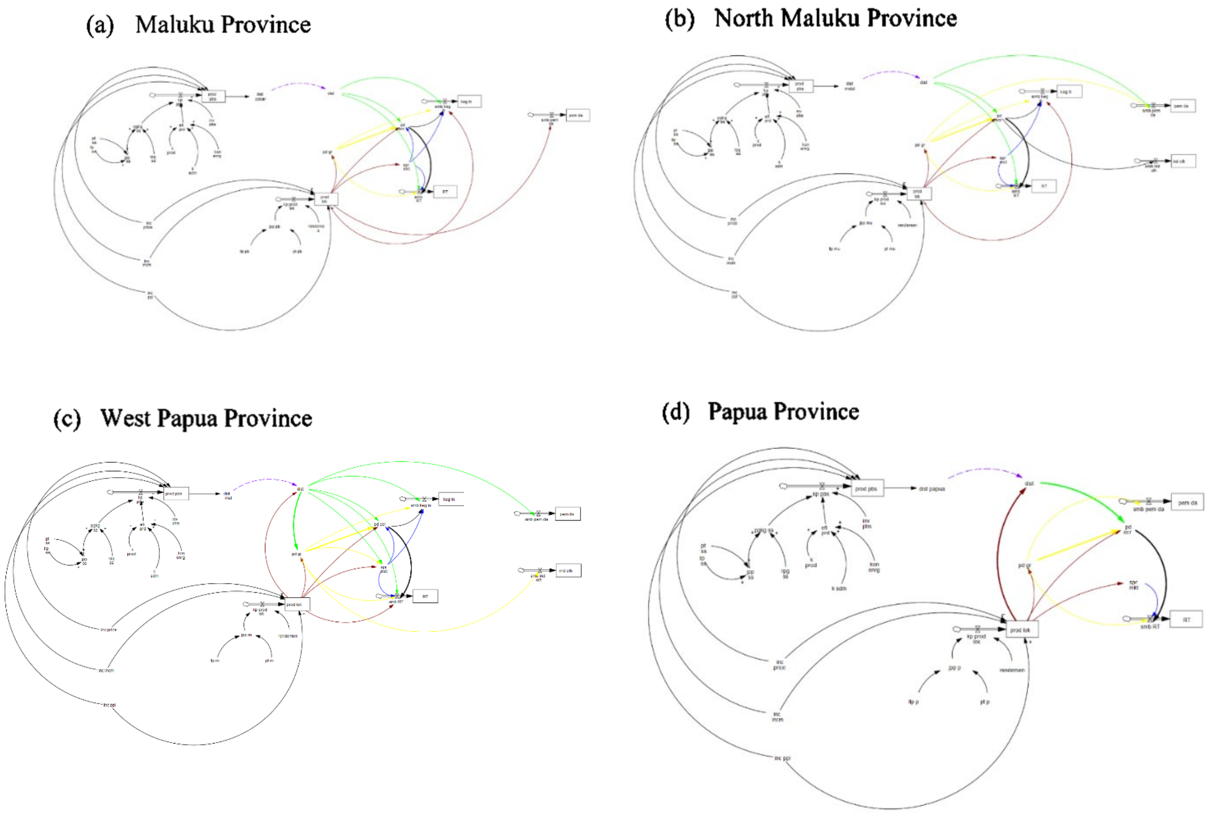

Fig. 5: Simulation Model of Rice Distribution System in East Indonesia using Vensim Software

3.5.3. Simulation Scenarios

Simulation scenarios become essential in comparing one scenario to another to determine which scenario yields optimal results for the rice distribution pattern system in the rice supply chain of each province in East Indonesia. Each scenario is run in a single simulation by varying independent variables or parameters in the system model. Some variables adjusted in the model include population growth of the province, annual increase in rice prices, increase in the Regional Gross Domestic Product (GDP) of the province, land area, and crop productivity per hectare in the province. The following is a description of each scenario applied in the dynamic system simulation.

Scenario 1 (Population growth rate and rice price increase). Each province has different growth rates. Maluku Province has population growth rate and rice price increase of 1.83% and 10%, North Maluku Province has 1.61% and 10%, West Papua Province has 3.94% and 10%, and Papua Province has 1.61% and 10%.

Scenario 2 (Population growth rate and rice price increase followed by an increase in harvested area for each province). The assumptions for the increase in harvested area for each province are different and based on empirical data. The increase in harvested area for Maluku Province is 2,000 hectares, North Maluku Province is 2,000 hectares, West Papua Province is 1,000 hectares, and Papua Province is 2,000 hectares.

Scenario 3 (Population growth rate and rice price increase followed by an increase in crop productivity for each province). The applied scenario for increasing crop productivity is the same for each province, which is 1.5 tons per hectare.

Scenario 4 (Population growth rate and rice price increase followed by an increase in production factors for each province). Production factors are essential in increasing rice supply in a region, which is why the scenario for increasing production factors is applied for each province with the same value of 10%.

Scenario 5 (Population growth rate and rice price increase followed by economic growth for each province). The population growth rate can represent the community's ability to acquire goods, including rice. Therefore, this scenario is important. The magnitude for each province varies depending on the economic conditions of each region. Maluku Province is 5%, North Maluku Province is 10%, West Papua Province is 2%, and Papua Province is 2.7%.

3.5.4. Dynamic System Model Validation

After the simulation results have been obtained, the next step will involve data validation to ensure that the created model can accurately depict the actual state of the system. System validation can be performed using mean comparison or variance comparison, both of which involve statistical comparisons between model output and input data (Mean Comparison and Variance Comparison, respectively) (Faster Eka Adipraja et al., 2018).

a. Means Comparison

$$E1 = \frac{[\bar{S} - \bar{A}]}{\bar{A}} \times 100\% \qquad (11)$$

Where:
$\bar{S}$ = The average value of simulation results
$\bar{A}$ = The average value of the data
A model is considered valid when E1 ≤ 5%

b. Variance Comparison

$$E2 = \frac{|Ss - Sa|}{Sa} \times 100\% \qquad (12)$$

Where:
Ss = The standard deviation of the model
Sa = The standard deviation of the data
A model is considered valid when E2 ≤ 30%

3.6. Data Collection

There are two types of data analyzed in this research: primary data and secondary data. The primary data collected in this study were gathered using various methods, including:

1. Field observation: The researcher collected data focusing on several rice supply chain stakeholders in the eastern region of Indonesia. The research employed purposive-snowballing sampling, where data was collected from farmers, collectors, and rice producers.

2. Interviews and discussions: Data collection also involved direct interviews and discussions with stakeholders involved in the rice supply chain in the eastern region of Indonesia.

3. Expert opinions: The researcher conducted interviews and gathered data from experts based on their experience and knowledge in the field of supply chain. The selection of experts in this research used purposive sampling, where expertise and availability were given high priority.

4. Publication of Government Institutions Data: The researcher collected data through the publication of government institutions related to the rice distribution system in the Eastern region of Indonesia.

4. Results

4.1. Rice Supply Chain Performance Measurement

The management of the various stakeholder-involved rice supply chain includes performance measurement as a key component. The objective of performance measurement is to enhance the company's performance by providing open and transparent communication among different stakeholders within the organization or business line (Kamble & Gunasekaran, 2020).

The use of SCOR-DS is highly beneficial for measuring supply chain performance. SCOR-DS has advantages over previous versions as it considers sustainability aspects. Performance measurement using SCOR is also comprehensive and systematic, serving as an evaluation tool for stakeholders and improving supply chain performance. As mentioned earlier, SCOR-DS includes eight performance attributes that are measured, namely reliability, responsiveness, agility, cost, profit, assets, environmental, and social.

In measuring the performance of the rice supply chain in the eastern region of Indonesia, up-to-date and accurate data is required. This data includes the weights of the metrics obtained from questionnaires distributed to experts, the actual metric values obtained from direct observations and interviews, and benchmark values for each stakeholder. Once these values are obtained, they will be formulated according to formulas 4 and 5. Subsequently, an analysis and description of the performance measurement results of the rice supply chain in the eastern region of Indonesia will be conducted.

The performance score calculation for each indicator begins with computing its monthly values over the course of one year. The actual values for each indicator are derived from field data variables, based on observations and interviews with stakeholders in the rice supply chain. As an illustration, the data used to calculate indicator RL 1.1 (Perfect Order Fulfillment) with a minimum target is presented in Table 4. The collected data varies significantly each month. The data variability for indicator RL 1.1 is attributed to the fluctuating quantity of rice orders from different customers each month. For example, in February and July, with values of 237.6 tons and 248.4 tons, respectively, are the highest values compared to other months due to a rapid increase in demand during those months. The obtained values are then calculated to obtain the indicator score, referring to the benchmark values. The benchmark value for this indicator is the quantity of customer orders for each month. To calculate the RL 1.1 indicator score, Formula 4 is applied, as follows:

$$Normalization\ 1\ of\ RL.1.1\ at\ January\ (x_1) = \frac{I_{i-\min(i)}}{B(I_{i)-\min(i)}} = \frac{136{,}8 - 85{,}2}{137{,}5 - 85{,}2} = 0{,}99$$

After obtaining the values for each month, the next step is to average those values to obtain the performance score for each indicator.

$$Normalization\ of\ RL.1.1 = \frac{\sum x_i}{n} = \frac{9{,}37}{12} = 0{,}78$$

Table 3. Normalization calculation for KPI Number 1, Perfect Order Fulfillment (RL 1.1)

Month	Min Value*	Max Value*	Actual Value*	Benchmark*	Normalized
January	85.2	270	136.8	137.5	0.99
February			237.6	239	0.99
March			99.6	104	0.77
April			93.6	95	0.86
May			85.2	88.5	0
June			270	276	0.97
July			248.4	258.5	0.94
August			116.4	124.5	0.79
September			90	94	0.55
October			111.6	117	0.83
November			103.2	107	0.83
December			115.8	121	0.85
			The average normalization		**0.78**

The importance of normalization in evaluating the performance of KPI RL 1.1 at 0.78 or 78% cannot be overlooked. This value truly reflects how far the company has reached its goals and targets concerning this KPI. Although this value is already quite satisfactory, the company still has the potential to further enhance it in the future.

To achieve this improvement, the company should consider more effective strategies. This may involve a reevaluation of existing processes, workflow optimization, the adoption of the latest technology, or additional training and development for employees involved in achieving this KPI. Continuous monitoring and analysis of the performance of KPI RL 1.1 are also crucial so that the company can identify improvement opportunities.

The importance of enhancing the value of KPI RL 1.1 should also be understood in the context of the company's supply chain. The performance of this KPI has a direct impact on the supply chain and the company's ability to meet customer demands, manage inventory, and optimize operational processes. Therefore, improving this value will have a positive impact on the entire company's supply chain, enabling greater efficiency and long-term cost savings.

The significance of the KPI RL 1.1 value is also evident in its integration with other KPIs. The final score of the company's supply chain performance is the result of summing all relevant KPIs. Hence, enhancing the value of KPI RL 1.1 will also positively contribute to increasing the final score of supply chain performance, which, in turn, will strengthen the company's position in the market and support its growth and sustainability.

Therefore, it is crucial for the company to commit to continuous improvement efforts and the implementation of appropriate strategies to ensure that the value of KPI RL 1.1 can be further elevated in the future. This is a significant step toward achieving competitive excellence and long-term success.

4.2. Rice Supply Chain Performance

The indicator weight determined from the pairwise comparison questionnaire of the Analytic Hierarchy Process (AHP) is then multiplied by the performance score for each indicator, as shown in Table 4.

$$
\begin{gathered}
Performance\ score\ of\ RL.1.1 \\
= W(I_i) \times N(I_i) = 0{,}78 \times 0{,}065 \\
= 0{,}0507 \times 100 = 5{,}07
\end{gathered}
$$

Table 4. Score for Rice Supply Chain Performance of Eastern Indonesia

No.	KPI Codes	Key Performance Indicator	Target	Normalized	Weight	Score
1	RL 1.1	Perfect order fulfillment	Max	0.78	0.065	5.07
2	CO 1.2	Cost of goods sold	Max	0.68	0.097	6.57
3	PR 1.1	Profit before interest and taxes	Max	0.79	0.140	11.00
4	PR 1.2	Effective tax rate	Max	1.00	0.061	6.10
5	SC 3.2	New employee recruitment	Max	0.92	0.016	1.47

6	SC 3.11	Career development	Max	0.94	0.019	1.79
7	RS 2.1	Order cycle time	Min	0.60	0.042	2.51
8	CO 2.2	Material acquisition cost	Min	0.94	0.074	6.94
9	AM 3.2	Days of supply in work-in-progress	Min	1.00	0.043	4.30
10	AM 3.3	Quantity of damaged inventory	Min	0.87	0.052	4.52
11	AG 2.3	Production capacity	Max	0.78	0.073	5.69
12	AG 2.4	Human resource capacity	Max	1.00	0.047	4.70
13	EV 1.2	Energy consumed	Min	0.78	0.032	2.48
14	EV 1.3	Water consumed	Min	0.53	0.018	0.95
15	EV 1.5	Waste generated	Max	0.46	0.012	0.55
16	SC 3.5	Health and safety	Min	1.00	0.033	3.30
17	RL 3.1	On-time delivery to customers	Min	1.00	0.039	3.90
18	RS 1.1	Order fulfillment cycle time	Min	0.75	0.082	6.13
19	AM 3.4	Quantity of excess inventory	Min	1.00	0.018	1.80
20	RL 3.11	Damage-free customer orders	Min	0.88	0.035	3.06
					Total Score	**82.85**
					Category	**Good**

The results of the performance score calculation for the rice supply chain in East Indonesia indicate a good performance with a score of 82.85. This score falls within the good category, which ranges from 80 to 84. However, since the score has not reached the excellent category, further analysis is needed regarding the performance indicators that have low scores and influence the overall calculation. Table 5 presents the performance indicators with low scores.

Table 5. Performance Indicators with Low Values

KPI Codes	No.	Key Performance Indicator (level 3)
RL 1.1	1	Perfect order fulfillment
CO 1.2	2	Cost of goods sold
PR 1.1	3	Profit before interest and taxes
RS 2.1	7	Order cycle time
AG 2.3	11	Production capacity
EV 1.2	13	Energy consumed
EV 1.3	14	Water consumed
EV 1.5	15	Waste generated
RS 1.1	18	Order fulfillment cycle time

Factors contributing to the low performance scores of each indicator are identified. Performance indicators RL 1.1 and AG 2.3 are determined by the company's ability to produce rice according to customer demand. Therefore, it can be said that the production capacity of the company still needs improvement.

Performance indicator CO 1.2 is determined by the company's ability to predict fluctuations in rice commodity prices. This is evident from the values indicating that the company is unable to determine prices that are appropriate or close to market prices. Good and keen market analysis skills are needed, especially regarding price fluctuations.

Additionally, the company is unable to achieve the set profit targets, as seen in the score of performance indicator PR 1.1. The rice company's management still needs to work hard to achieve the predetermined profit targets. The company's profit is also influenced by the performance of the material ordering cycle, as indicated by performance indicator RS 2.1, and the customer order fulfillment cycle, as indicated by performance indicator RS 1.1.

Performance indicator RS 2.1 is affected by delayed arrival of paddy compared to the management's previous predictions. In addition to the distance between paddy suppliers, the harvest period also affects the situation. This can occur when there is an increased demand for paddy during the harvest period, which can affect the transportation capacity of the logistics or transport services that deliver paddy to the rice milling company.

If performance indicator RS 2.1 is more influenced by the paddy supplier's side, performance indicator RS 1.1 is influenced by the company's side in fulfilling customer orders, which is also affected by inter-provincial transportation services. During religious holidays, deliveries can be affected due to high transportation volume, and products other than rice or other food items also need to be delivered.

Indicators within the production process also greatly influence the performance of the rice supply chain. There are three performance indicators that need to be considered in the production process, namely performance indicators EV 1.2, EV 1.3, and EV 1.5. These three indicators are part of the environmental aspect, which is also an important component of the SCOR-DS 14.0 framework.

Performance indicator EV 1.2 measures the company's ability to carry out production with minimal electricity consumption. From the scores obtained, it is still evident that the company needs to improve the efficiency of electricity usage to meet the desired standards. Additionally, water consumption in the production process is still high, as indicated by the score of performance indicator EV 1.3. High water consumption is influenced by the methods and facilities within the company. Bathing, washing, and toilet facilities still use conventional containers such as buckets, resulting in poorly controlled water usage by the workforce. This can lead to high future operational costs.

Furthermore, there is a performance indicator EV 1.5 related to waste. Rice waste in the production process has value and can provide benefits to the company. Rice husks can be utilized, such as for organic fertilizer, animal feed, alternative fuel for power generation, or grain drying ovens. Rice husks can also be used as bran for organic fertilizer, animal feed, mushroom cultivation substrate, and raw material for bioethanol (Priyadi et al., 2023).

With the economic benefits of the generated waste, the milling company should produce an ideal amount of rice husks. However, the calculated score of performance indicator EV 1.5 has not yet reached the ideal value. The efficiency of the machines used in the production process has not achieved the ideal target, indicating the need for improvement in the future. Thus, the company can obtain greater benefits from the rice husk waste generated in the rice production process.

4.3. Dynamic System Simulation of Rice Distribution in Eastern Indonesia

To create an optimal distribution pattern in rice supply in Eastern Indonesia, particularly in the four provinces under study, a simulation process is required. Dynamic System Simulation (SD) aims to understand the relationships and influences between variables in a real-world system. Thus, independent variables in the Dynamic System can be determined to what extent they can provide optimal outcomes for the system in practice. The results of the rice distribution patterns simulation in the four provinces of Eastern Indonesia can be seen in Figure 6.

This simulation was conducted using Vensim software, where five different scenarios were applied in each province. The first scenario involved increasing the population, which varied among provinces, along with rising rice prices in each respective province. The second scenario included expanding the cultivated land area in each province in response to the population increase and rice price hike.

The third scenario focused on enhancing agricultural productivity in each province, followed by population growth and rising rice prices. The fourth scenario considered increasing rice production capacity in each province in response to the same dynamics. The fifth scenario linked this increase with economic growth or Gross Regional Domestic Product (GRDP) in each region.

The results of each scenario yielded varying values, and to visualize them, Figure 6 was used. In this figure, we differentiate the graphs for each scenario using different colors, making it easier to understand the impact of each scenario on the rice distribution pattern in the region.

Table 6. Results Of The Simulation Applying The Third Scenario For Each Province

Province	Scenario 3 (tons/year)					
	2022	2023	2024	2025	2026	2027
Maluku	81.716,20	163.432	317.198	543.012	840.876	1,21E+11

North Maluku	19.403,70	47.380,80	92.505	154.776	234.194	330.760
West Papua	15188	36911,4	71705,7	119571	180507	254513
Papua	192.748	385.497	748.615	1,28E+10	1,99E+11	2,86E+11

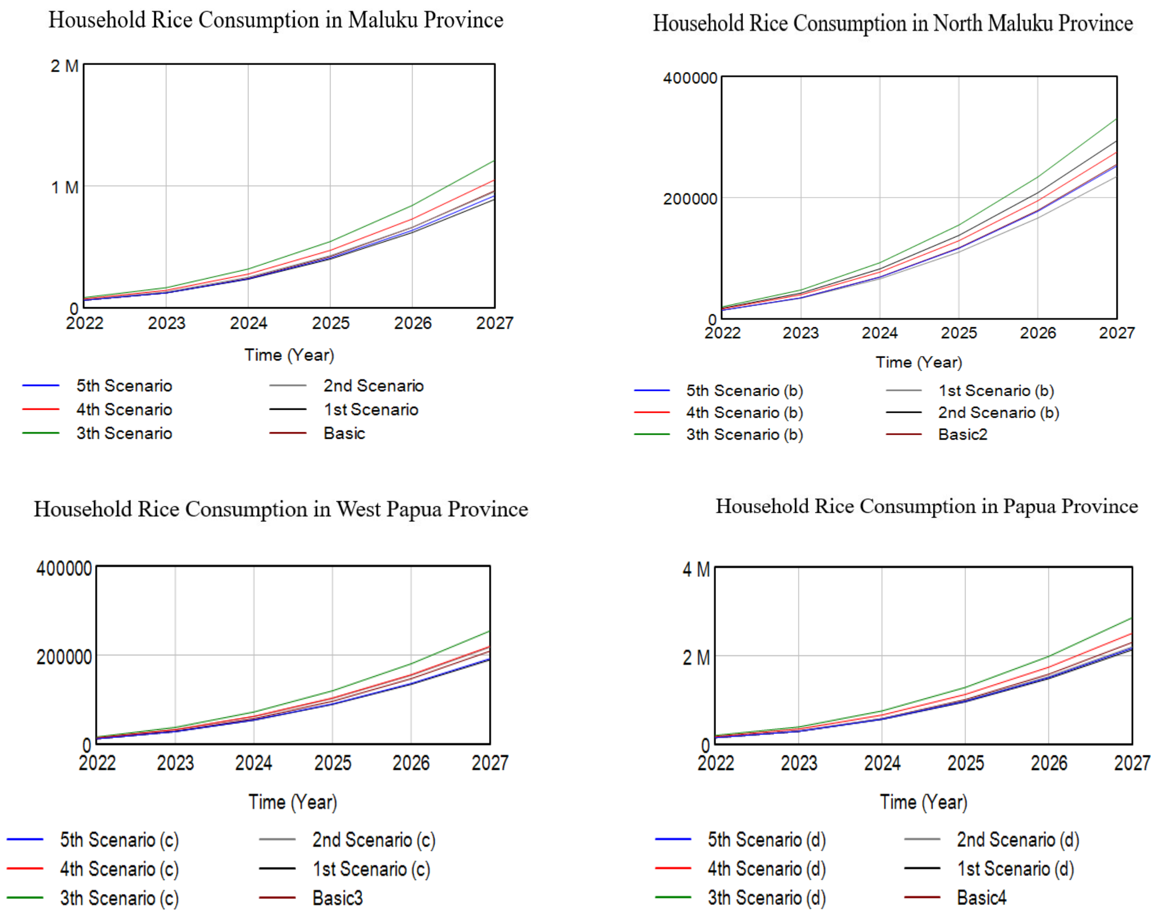

Fig. 6: The Results Of The Simulation For The Household Rice Supply System In Eastern Indonesia.

The results of the simulation in Figure 6 provide concrete evidence that implementing the third scenario in all provincial simulations yields an optimal rice supply level. This phenomenon underscores the significant potential for enhancing rice production across the country, not only to meet household consumer needs but also to strengthen the national rice reserves. In other words, the potential for increasing planting capacity in each province has a highly significant positive impact in ensuring an adequate supply of rice for all stakeholders.

Therefore, the primary conclusion drawn from these findings is the necessity for further efforts to optimize rice cultivation potential in all provinces. This will greatly benefit in reducing dependence on external supply sources and enhancing the nation's food sovereignty. For more comprehensive and detailed simulation information, please refer to Table 6 below, which provides a thorough analysis of the positive impacts of implementing the third scenario in driving rice sector growth at the provincial level.

4.4. Validation of simulation results

After the simulation results have been obtained, the next step will involve data validation to ensure that the created model can accurately depict the real state of the system. System validation can be carried out using mean comparison or variance comparison, both of which involve comparing the statistical outputs of the model with input data (Mean Comparison and Variance Comparison, respectively) (Faster Eka Adipraja et al., 2018)

The validation process of the simulation model for the dynamic rice distribution pattern in the provinces of Maluku, North Maluku, Papua, and West Papua uses formulas 11 and 12. The results can be seen in Table 7.

Table 7. Simulation Model Validation Results

No.	Production Area	Production Output Data (Tons)	Simulation of Production Data (Tons)
1	Sidrap Rice Mill	1.708,2	1731,5
2	The Production in the Maluku Province	65.000	64235
3	The Production in the North Maluku Province	16.000	15968,6
4	The Production in the Papua Province	16.000	16165,6
5	The Production in the West Papua Province	163.000	162982
Mean		52.341,6	52216,5
Standard Deviation		66.352,6	66.286,7
E1≤ 5%		**0,24%**	
E2≤ 30%		**0,1%**	

Based on Table 4.88, the value of E1 is 0.24%, which is ≤ 5%, and the value of E2 is 0.1%, which is ≤ 30%. Therefore, the model is considered valid and verified according to the actual rice distribution pattern system conditions.

5. Discussion

This research offers significant insights into rice supply chain management in Indonesia. The use of SCOR-DS metrics as a performance evaluation tool has introduced a holistic approach to measuring and understanding supply chain performance. Findings from this study provide evidence that, in general, the performance of the rice supply chain in Indonesia, especially in Eastern Indonesia, can be categorized as good. For example, in a study focused on Bolaang Mongondow, the research highlights distribution issues. Although the rice production process runs relatively smoothly, there are still inefficiencies in the distribution channels that can result in delays in delivering rice to end consumers (Tiwu et al., 2019) . In the context of the rice supply chain in Gorontalo, Papua, and Temanggung, the findings indicate that supply chain management is still suboptimal in some regions. This includes the dominance of intermediaries in the supply chain, which can affect resource allocation and overall efficiency (Djama et al., 2023; Manupapami et al., 2021; Palupi et al., 2020).

In other words, previous studies have underscored imperfections in the rice supply chain processes in Indonesia. While the quality of rice itself may be good, there is still room for improvement in terms of efficiency, transparency, and supply chain sustainability. These findings emphasize that more holistic performance evaluations and integrated approaches in rice supply chain management are essential steps in addressing these challenges and ensuring a reliable and sustainable rice supply for the people of Indonesia.

This research also contributes theoretically by providing a more comprehensive view of rice supply chain performance and introducing a more comprehensive evaluation tool in the form of SCOR-DS metrics. Additionally, the use of dynamic system simulations highlights the importance of data-driven planning to optimize the supply chain and provides a deeper understanding of the impacts of changes in the supply chain.

The practical implications of this research are highly relevant in real-world contexts. Recommendations such as increasing production capacity, improving market analysis, and emphasizing environmental sustainability provide concrete guidance to stakeholders involved in the rice supply chain in Indonesia. These measures can help improve the overall supply chain, enhance food security, and support economic growth, especially in eastern Indonesia.

Thus, this research not only provides a better understanding of rice supply chain performance in Indonesia but also offers practical solutions and recommendations that can be applied to enhance food security and economic growth. Overall, this study bridges the gap between theory and practice in rice supply chain management in Indonesia, with the hope of providing valuable guidance to stakeholders in their efforts to improve a more efficient and sustainable supply chain in the future.

6. Conclusion

This study analyzes the rice supply chain in Eastern Indonesia using SCOR performance measurement and system dynamics simulation. The findings indicate an overall good supply chain performance, while identifying specific improvement areas related to production capacity, cost control and sustainability. Additionally, increasing planting area and productivity through system dynamics simulation demonstrates potential to optimize rice supply for household needs. This provides practical insights for enhancing efficiency, sustainability and food security in Indonesia's rice supply chain. The research makes valuable theoretical contributions by addressing gaps in understanding rice supply chain dynamics.

Further studies can build on this work by undertaking comparative analyses, qualitative research, and investigating additional supply chain optimization strategies. Overall, the study delivers important guidance for rice supply chain stakeholders and academics aiming to strengthen Indonesia's agricultural sector.

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References

Afrianto, I., Djatna, T., Arkeman, Y., Sukaesih Sitanggang, I., & Hermadi, I. (2020). Disrupting Agro-industry Supply Chain in Indonesia with Blockchain Technology: Current and Future Challenges. *2020 8th International Conference on Cyber and IT Service Management, CITSM 2020*. https://doi.org/10.1109/CITSM50537.2020.9268872

Aido, I., Erry Prasmatiwi, F., & Adawiyah (2021). Consumption Pattern and Household Demand on Rice in Bandar Lampung City. In *Jurnal Ilmu Ilmu Agribisnis: Journal of Agribusiness Science*, 9(3).

ASCM, 2022. *Scor Digital Standard*. W. Bryn Mawr Ave,3-4.

Asrol, M., & Soinangun, B. (2022). Optimization Spare Parts Storage in Multi-Warehouse Petrochemical Plant Thru Fuzzy Logic. *Article in Academic Journal of Manufacturing Engineering*.

Azmiyati, S., & Hidayat, S. (2016). Performance Measurement of the Supply Chain at PT. Louserindo Megah Permai Using the SCOR and FAHP Models. *Al-Azhar Indonesia Journal Series on Science and Technology*. *3*(4), 163 - 170.

Behzadi, G., O'Sullivan, M. J., Olsen, T. L., & Zhang, A. (2018). Allocation flexibility for agribusiness supply chains under market demand disruption. *International Journal of Production Research*, *56*(10), 3524–3546. https://doi.org/10.1080/00207543.2017.1349955

Boateng, A. (2019). Supply Chain Management In The Ghanaian Building Construction Industry: A Lean Construction Perspective. *Creative Cosntruction Conference 2019* (pp. 430–439). Budhapest University of Technology and Economics. https://doi.org/10.3311/ccc2019-060

Defrizal, D., Hakim, L., & Kasimin, S. (2020). Analysis of Rice Supply Chain Performance Using the Supply Chain Operation Reference (SCOR) Model and Analytical Hierarchy Process (AHP) Method (Case Study: CV. Meutuah Baro Kuta Baro Aceh Besar District). *International Journal of Multicultural and Multireligious Understanding*, *7*(7), 222. https://doi.org/10.18415/ijmmu.v7i7.1731

Djama, A., Indriani, R., & Moonti, A. (2023). Optimizing Rice Supply Chain Management for Food Security Maintenance. *Media Agribisnis*, *7*(1), 107–115. https://doi.org/10.35326/agribisnis.v7i1.3199

Faster Eka Adipraja, P., Arbian Sulistyo, D., & ASIA Malang, S. (2018). Dynamic System Modeling for Daily Rainfall Intensity Prediction in Malang City. *Jurnal Ilmiah Teknologi Informasi Asia*, *12*(2).

Gunawan, F., 2022. *Introduction to System Dynamics, Discrete-Event Simulation, and Agent-Based Simulation*. BINUS University,10-12.

Kamble, S. S., & Gunasekaran, A. (2020). Big data-driven supply chain performance measurement system: a review and framework for implementation. *International Journal of Production Research*, *58*(1), 65–86. https://doi.org/10.1080/00207543.2019.1630770

Kesy Garside, A., Hasyim, ;, & Asjari, Y. (2015). Simulation of Rice Availability in East Java. *Scientific Journal of Industrial Engineering*, *14*(1), 47 – 58.

Kunnapapdeelert, S., & Pitchayadejanant, K. (2021). Analyzing the effect of supply chain strategies and collaboration on performance improvement using MIMIC model. *International Journal of Industrial Engineering and Management*, *12*(3), 216–225. https://doi.org/10.24867/IJIEM-2021-3-289

Mageto, J. (2021). Big data analytics in sustainable supply chain management: A focus on manufacturing supply chains. *Sustainability (Switzerland)*, *13*(13). https://doi.org/10.3390/su13137101

Manupapami, F., Wullur, M., Jan, A., & Lodewyk, R. (2021). Analysis Of Rice Supply Chain Network System In Muram Sari Village, Merauke Regency, Papua Province. *EMBA Journal*, *9*(2), 840–847.

Marimin, Djatna, T., MacHfud, Asrol, M., Papilo, P., Taufik, B., & Darmawan, M. A. (2020). Supply chain performance measurement and improvement of palm oil agroindustry: A case study at Riau and Jambi Province. *IOP Conference Series: Earth and Environmental Science*, *443*(1). https://doi.org/10.1088/1755-1315/443/1/012056

Octania, & Galuh. (2021). *The Government's Role in the Indonesian Rice Supply Chain* (No. 32). Policy Paper.

Palupi, A., Priyanto, S. H., & Sunaryanto, L. T. (2020). Dynamics of the Rice Supply Chain in Bansari Subdistrict, Temanggung Regency. *AGRISEP Journal: Studies in Agricultural and Agribusiness Socioeconomic Issues*, *19*(2), 361–374. https://doi.org/10.31186/jagrisep.19.2.361-374

Pratama, A. R., Sudrajat, S., & Harini, R. (2019). Analysis of Rice Availability and Demand in Indonesia in 2018. *Geography Communication Media*, *20*(2), 101. https://doi.org/10.23887/mkg.v20i2.19256

Priyadi, R., Sunarya, Y., Hilman Juhaeni, A., & Cahya Azhari, S. (2023). Training on Processing Rice Husks into Bran and Fermenting Bran Using M-Bio to Enhance the Economic Livelihoods of Women Farmer Groups in Setiawaras Village, Tasikmalaya Regency. *Journal of Women and Children in Indonesia*, *4*(2), 54–59. https://doi.org/10.35801/jpai.4.2.2023.44895

Putra, A. W., Supriatna, J., Koestoer, R. H., & Soesilo, T. E. B. (2021). Differences in local rice price volatility, climate, and macroeconomic determinants in the Indonesian market. *Sustainability (Switzerland)*, *13*(8). https://doi.org/10.3390/su13084465

Radhi, F., & Hariningsih, E. (2021). The Impact of Supply Chain Management Integration on Operational Performance. *Wahana: Journal of Economics, Management, and Accounting*, *24*(1), 116–132. https://doi.org/10.35591/wahana.v24i1.328

Saeri, M., Lotfi, M. M., & Mazidi, M. R. (2019). A Causal Loop Diagram to Analyze Various Long-Term Effects of PV Integration into Power Systems. *27th Iranian Conference on Electrical Engineering (ICEE2019)*.

Santosa, M., Winaktoe, W. W., Widhianthini, P. N. S., Putra, A. R. S., Aditya, A., Respati, T., & Sumargo, B. (2020). *Sistem Dinamik untuk Pembangunan Berkelanjutan*. Asosiasi Sistem Dinamik Indonesia.

Setiawan, H., Damayanty, S. A., & Tenrini, R. H. (2020). Supply Chain Management for Value Added in Agriculture Sector of Indonesia. *International Journal of Supply Chain Management, 9*(3), 1280 – 1287.

Song, J., Tang, B., Zhang, J., Dou, X., Liu, Q., & Shen, W. (2018). System dynamics simulation for optimal stream flow regulations under consideration of coordinated development of ecology and socio-economy in the Weihe River Basin, China. *Ecological Engineering*, *124*, 51–68. https://doi.org/10.1016/j.ecoleng.2018.09.024

Sukereman, A. S., Ab Rahim, N., Zainol, N. N., Azmi, N. A., & Nordin, M. S. A. (2022). The state of food security: A comparative study between Malaysia, Singapore, and Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1067*(1). https://doi.org/10.1088/1755-1315/1067/1/012009

Sutoni, A., Subhan, A., Setyawan, W., Bhagyana, F. O., & Mujiarto. (2021). Performance Analysis Using the Supply Chain Operations Reference (SCOR) and AHP Method. *Journal of Physics: Conference Series*, *1764*(1). https://doi.org/10.1088/1742-6596/1764/1/012155

Syed, S., Manji, K., McDonald, C., Kisenge, R., Aboud, S., Sudfeld, C., Locks, L., Liu, E., Fawzi, W., & Duggan, C. (2018). Biomarkers of Systemic Inflammation and Growth in Early Infancy are Associated with Stunting in Young Tanzanian Children. *Nutrients*, *10*(9), 1158. https://doi.org/10.3390/nu10091158

Tiwu, W. H. L., Sepang, J. L., & Rate, P. V. (2019). Analysis Of Ricesuplly Chain Distribution Channels In Bolaang Mongondow. *EMBA Journal*, *7*(1), 1031–1040.

Trueba-Castañeda, L., Sanz, D. S., & Trueba, A. (2022). Analysis of the supply chain in commercial ports by SCOR model. *Journal of Maritime Research, 19*(3), 1 – 8.

Umaran, T., Perdana, T., Kurniadie, D., & Parikesit, P. (2022). Co-Creation Approach in Designing a Sustainable Coffee Supply Chain (a Case in Bandung Regency, West Java, Indonesia). *Sustainability (Switzerland)*, *14*(1). https://doi.org/10.3390/su14010476

Wang, C. N., Huang, Y. F., Cheng, I. F., & Nguyen, V. T. (2018). A Multi-Criteria Decision-Making (MCDM) Approach Using Hybrid SCOR Metrics, AHP, and TOPSIS for supplier evaluation and selection in the gas and oil industry. *Processes*, *6*(12). https://doi.org/10.3390/pr6120252