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Leveraging Agri-Food Strategies Through SWOT Analysis Embedded Into the Business Model Canvas: Insights from the Seaweed Industry in East Nusa Tenggara Province, Indonesia

[1]Budi Wardono, [2]Adhita Sri Prabakusuma, [3]Risna Yusuf, [4]Maharini Yulisti, [5]Irwan Mulyawan, [6]Estu Sri Luhur
[1]Research Center for Cooperative, Corporation, and People's Economy, National Research and Innovation Agency, Indonesia
[2]Vocational School of Foodservice Industry, Universitas Ahmad Dahlan, Indonesia
[3,4,5,6]Ministry of Maritime Affairs and Fisheries, Indonesia
adhita.sriprabakusuma@tp.uad.ac.id

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ABSTRACT

Abstract: The seaweed industry in the agri-food sector faces significant challenges, such as fluctuating market demand, environmental constraints, and economic pressures, requiring strategic and adaptive solutions. This study explored the integration of SWOT analysis with the Business Model Canvas (BMC) as an innovative approach for strategic planning in the seaweed industry in East Nusa Tenggara (NTT) Province, Indonesia. A mixed-method approach was employed, combining qualitative and quantitative data collection. Qualitative data were gathered through purposive sampling through focus group discussions and in-depth interviews with key stakeholders and experts. Quantitative analysis was conducted using the Analytical Hierarchy Process (AHP) to prioritize strategies derived from the SWOT-BMC integration. The SWOT factors were embedded into the BMC framework to analyze strategic elements. The AHP results revealed that the highest priority strategy (W-O) emphasized innovation and infrastructure improvement through collaboration with government and private stakeholders (weight of 0.122). This strategy focuses on modernizing processing facilities and enhancing supply chain management to ensure consistent product quality and increase capacity to meet global market demand. In contrast, leveraging government support and local natural resources (S-O) was ranked lower in priority (weight of 0.081). Key BMC elements—key activities, key resources, and value propositions—were strengthened by incorporating W-O, S-T, and W-T strategies. This integrated SWOT-BMC approach provides a comprehensive framework for the seaweed industry to drive innovation, enhance competitiveness, and promote a sustainable food system. The study's practical implications highlight the importance of targeted investments in technology and infrastructure to ensure long-term success in the global market.

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A. LATAR BELAKANG

Aquaculture production has contributed almost half of the world's fisheries production, from only 14.64 percent in the 1980s to 45.99 percent in 2018 (FAO, 2020). Mariculture, or marine aquaculture, contributes 37.5 percent to aquaculture production. Coastal and mariculture-based businesses play a positive role in terms of foreign

exchange earnings, as well as in providing sustainable livelihoods, employment potential, and local economic development for coastal communities in many developing countries (FAO, 2020, 2022; Firdaus et al., 2023). Mariculture, the fastest-growing animal-based food industry, has become a key driver in achieving the Sustainable Development Goals (SDGs), particularly in food security, economic growth, and the use of marine resources. This industry's output has increased significantly, from 2.4 million metric tons in 2010 to 6.4 million metric tons in 2019. In 2024, Indonesian mariculture industry set a target to achieve a 10.4% yearly increase in production volume (Napitupulu et al., 2022). The Ministry of National Development Planning of the Republic of Indonesia (BAPPENAS) established a goal for annual per capita fish consumption of 62 kg in 2024, an increase of 6.9% from 58 kg in 2019 (Hapsari et al., 2024; Napitupulu et al., 2022).

This remarkable growth, termed the "blue revolution," underscores aquaculture's potential to address global food shortages, support economic resilience, and improve livelihoods, particularly in coastal and island nations (Firdaus et al., 2023). As Asia leads global aquaculture production, with China dominating and Indonesia ranking second, sustainable aquaculture and mariculture practices are essential for ensuring long-term environmental protection and responsible resource management, aligning closely with the SDGs by promoting balanced ecological and economic development in marine-based sectors (Henriksson et al., 2019; Troell et al., 2023). The Indonesian Ministry of Marine Affairs and Fisheries (MMAF) has primarily concentrated on the marine, coastal, and terrestrial aquaculture sectors. MMAF boasts a selection of exquisite commodities, including shrimp, seaweed, tilapia, lobster, and crab (Mahmud et al., 2021; Wardono et al., 2023). Shrimp is a major mariculture commodity in Indonesia and a key export in the marine and fisheries sector. However, seaweed is the largest commodity in this industry. Indonesia ranks as the world's second-largest seaweed producer, following China. In 2022, the exports of Indonesian seaweed and other algae reached an impressive volume of 231,829.70 tons, with a total value of US$397.16 million. The amount of seaweed exported from Indonesia increased by 12.44% compared to the previous year and the exports totaled 206,185.10 metric tons, with a value of US$222.61 million (Wardono et al., 2023).

Nowadays, Indonesia plays a significant role in the global seaweed trade, contributing approximately 40% of the world's total seaweed production and over 30% of global seaweed exports. Indonesia focuses particularly on red seaweeds or Rhodophyta, such as *Kappaphycus alvarezii*, *Eucheuma cottonii* (*E. cotonii*), and *Eucheuma denticulatum*, for carrageenan production, while Gelidium, Gelidiella, Pterocladia, and Gracilaria species are used to manufacture agar and alginate. Carrageenans, agar, and alginate are valuable seaweed-derived hydrocolloids, extensively used for their gelling and thickening properties in food, biotechnology, and pharmaceutical industries. Currently, around 99% of cultivated seaweed is utilized in the production of these agents for the pharmaceutical and food sectors (Prabakusuma et al., 2020; Rhein-Knudsen et al., 2015; Wardono et al., 2023). Since 2015, Indonesia emerged as a dominant player in the global hydrocolloid seaweed market. The country accounted for an impressive 65% of the global production of Kappaphycus and 56% of Eucheuma. Subsequently, Indonesia has continued to

experience rapid growth in this sector, solidifying its position as a key supplier in the industry (Rimmer et al., 2021). Seaweed was traditionally a common food in Asia, South America, and the Pacific Islands, but recent scientific research has focused on their potential as nutraceutical and functional foods to improve human health.

MMAF has implemented strategies to enhance mariculture productivity, specifically in seaweed industrial development, by implementing relevant policies, innovative techniques, and upgrading the cultivation, storage, processing, and distribution systems. MMAF accomplishes long-term strategic programs to foster an eco-friendly economy, safeguard and enhance delicate island ecosystems, mitigate disputes over marine and coastal utilization, enhance the well-being of coastal communities, and uphold the long-term viability of coastal ecosystems (FAO, 2024; Hapsari et al., 2024). To optimize Indonesian mariculture potential and enhance the welfare of marine and fisheries communities, a comprehensive approach to improving product quality and competitiveness and advancing the mariculture business chain from upstream to downstream is essential (AIP-PRISMA, 2016; Sunadji & Lukas, 2023). Exporters highly regard seaweed from East Nusa Tenggara (NTT) Province, one of the largest seaweed producers in Indonesia, for its excellent gel strength, high yield, and viscosity, as well as its cultivation in relatively unpolluted ecosystems. The production of dried seaweed, carrageenan, agar, and alginate processed from NTT Province's seaweed, holds substantial economic significance as a key mariculture product in Indonesia. It contributes both to local livelihoods and to foreign exchange earnings (AIP-PRISMA, 2016; Wardono et al., 2023). However, the seaweed sector faces various challenges, including volatile market demand, environmental limitations, and economic fluctuations, which necessitate adaptive and innovative strategies (Rimmer et al., 2021).

Despite the promising opportunities in the seaweed business, many farmers in NTT Province remain in poverty due to several key challenges. Low productivity, exacerbated by global climate change, and limited access to information on cultivation techniques and post-harvest handling are major issues. Farmers in remote regions struggle to access capital and financial resources, while local village traders often fail to provide sufficient information on the quality standards required by exporters (Sunadji & Lukas, 2023). Farmers also face low sales prices due to high operational costs, particularly expensive transportation from inland and island regions (Rimmer et al., 2021). This results in a disjointed supply chain, where weak knowledge transfer and high logistical costs hinder farmers' ability to meet the quality standards demanded by manufacturers and exporters (Ahmed et al., 2024). The main objective of this research was to integrate SWOT analysis with the BMC to formulate a strategic framework for the development of the seaweed industry in NTT Province. By embedding SWOT factors within the BMC model, the study aimed to identify internal strengths and weaknesses, as well as external opportunities and threats, to improve decision-making process in this sector. The significance of integrating SWOT with BMC lies in its ability to provide a comprehensive approach to effective strategic planning. This integration offers a comprehensive tool for aligning business activities with market demands, fostering innovation, improving infrastructure, and

ensuring sustainable development of the agri-food sector, all of which are critical for the seaweed industry in a dynamic global market.

B. METODE PENELITIAN

1. Research Sites and Data Collection

This recent study design developed following previous research framework performed by Wardono et al. (2021; 2023), which employed non-numerical data collection and analysis, including text, audio, and video, to explore stakeholder experiences and perspectives at the upstream level of the seaweed industry (Arthatiani et al., 2021; Wardono et al., 2020, 2023). The method was successfully applied in these prior studies to gain deep insights into complex industry challenges and inform the present research. With a keen focus on Kupang City, NTT Province (S 10°36'14" to 10°39'58", E 123°32'23" to 123°37'01"), a prominent hub for seaweed production in Indonesia, and its surrounding areas, this study explores into the potential that was untapped of strengthening the local agri-food system. Specifically, it aimed to explore the prospects of community-driven seaweed industrial development.

2. Research Methodology and Data Collection

This study employed both qualitative descriptive and quantitative analytical methods. The qualitative descriptive approach was performed through several techniques. First, direct observation was conducted, where the researchers observed the objects or people under study without any interaction, ensuring an unbiased collection of data. Second, semi-structured interviews were carried out through face-to-face or telephone interactions between the interviewer and respondents to gather in-depth insights. Third, the study involved a comprehensive desk study of scholarly articles, books, official websites, and other relevant sources. This step aimed to provide a detailed description, summary, and critical evaluation of existing literature pertinent to the research area. The overall goal of the qualitative descriptive analysis was to identify the current conditions in the field and interpret the research findings within a broader context (Citraresmi & Haryati, 2021; Mustaniroh et al., 2020).

In parallel, quantitative analysis was applied to prioritize alternative strategies using the Analytical Hierarchy Process (AHP) method. This method was chosen for its ability to structure complex decisions and evaluate the relative importance of different factors. The selection of expert respondents followed a purposive sampling approach (Ardhana et al., 2021; Tenny et al., 2024). Fifteen seaweed farmers, five managers from seaweed processing plants, and five experts from the MAFF were identified as key participants in the study. Their expertise and experience provided valuable insights into the seaweed industrial development in NTT Province. The research was conducted in several distinct stages. First, the AHP hierarchical levels were established, including the overall goals and objectives (leveraging agri-food strategies), criteria consisting of four groups of SWOT factors (strengths/S, weaknesses/W, opportunities/O, and threats/T), sub-criteria identified as key factors from the SWOT matrix (S–O, W–O, S–T, and W–T), and alternative strategies formulated according to the SWOT analysis of the seaweed agri-food industry

business model (Citraresmi & Haryati, 2021; Rezagama et al., 2021). These hierarchical levels structured the decision-making framework for analyzing the seaweed industry.

3. Data Analysis

In this study, the paired comparison data were analyzed using Expert Choice software version 11 (https://www.expertchoice.com/ahp-software). This software enabled the prioritization of the alternative strategies by comparing them in pairs based on the expert evaluations. This step was critical in determining which strategies would have the most significant impact on improving the seaweed industry in NTT Province. The current business model of the seaweed industry cluster was developed using the Business Model Canvas (BMC) approach (Citraresmi & Haryati, 2021; Mustaniroh et al., 2020). The alternative strategies identified through AHP analysis were integrated into this model to create a more robust framework for the industry's growth. The BMC approach provided a comprehensive overview of the potential pathways for enhancing the seaweed industry. This combination of qualitative and quantitative methods allowed for a detailed analysis of the seaweed industry, offering both a clear understanding of the current situation and a strategic roadmap for future development.

C. RESULTS AND DISCUSSION

1. Seaweed Potential Development and Production Volume in NTT Province

Until 2022, South Sulawesi remained the largest producer of seaweed in Indonesia, followed by regions such as NTT, Central Sulawesi, West Nusa Tenggara, East Java, Southeast Sulawesi, and North Sulawesi Provinces. In NTT Province, annual production of seaweed was recorded at 1.403 million tons, with a cultivation area of 54,000 hectares. However, this represented a decrease from 2.158 million tons per year in 2020, with the lowest production occurring in 2021 at just 1.392 million tons per year (Central Agency of Stratistics NTT, 2024). The decline was likely attributed to the adverse effects of the coronavirus disease 2019 (COVID-19) pandemic in 2020–2021 (Wardono et al., 2023). Following the pandemic, both local and central governments implemented several strategic interventions to revitalize the seaweed sector in NTT Province, including the establishment of seaweed nurseries in East Sumba and Kupang Regencies, as well as the initiation of four seaweed cultivation clusters in key production centers (AIP-PRISMA, 2016).

These seaweed cultivation clusters were organized geographically: Cluster I for Sumba (potential area of 10.600 Ha and annual production volume of 225.449 tons), Cluster II for Timor and Rote (potential area of 12.266 Ha and annual production volume of 1.593 million tons), Cluster III for Sabu (potential area of 3.955 Ha and annual production volume of 75.215 tons), Cluster IV for Alor, Lembata, and East Flores (potential area of 10.446 Ha and annual production volume of 81.774 million tons), and Cluster V for Sikka-West Manggarai (potential area of 15.445 Ha and annual production volume of 2.517 million tons) (Sunadji & Lukas, 2023). Additionally, processing plants were constructed in four of the five clusters to support local production and improve

supply chain efficiency. These initiatives were aimed at boosting seaweed production output and ensuring industrial growth in the post-pandemic period.

2. Seaweed Development Problems in NTT Province and the Problem-Solving Programs

Seaweed production in Indonesia, particularly in NTT Province, has faced significant challenges in terms of quality since last two decades (Mahmud et al., 2021; Waters et al., 2019). Farmers' dried seaweed products frequently do not meet the standards required by the processing industry and exporter company, leading to additional sorting costs for processors (Sunadji & Lukas, 2023). This situation weakens the bargaining position of seaweed farmers, making it difficult for them to compete in the market. In response to these issues, the Indonesian government implemented regulatory measures, including Presidential Decree No. 33 of 2019, which provides a roadmap for the development of the seaweed industry. This decree outlines key challenges such as ensuring the sustainable supply of quality raw materials, managing fluctuating seaweed prices, and improving cultivation and postharvest practices to meet industrial and export demands (Arthatiani et al., 2021; Wardono et al., 2023). The Indonesian National Standard (SNI) for seaweed cultivation and postharvest management has been introduced to address these issues. Specific SNIs include SNI No. 7672:2011 on *E. cottonii* seaweed seeds; SNIs No. 7673.1:2011, No. 7673.2:2011, and No. 7673.3:2011 on *E. cotonii* seaweed seed production – Part 1: Fixed-off-bottom method, Part 2: Longline method, and Part 3: Floating bamboo raft method cultivation, respectively; and SNI 2690:2023 on dried seaweed: Quality and processing requirements. These standards aim to improve the availability of high-quality raw materials for the seaweed processing industry, ensuring their consistency in quality for both domestic use and export. The implementation of national standards provides clear guidelines for small and medium-scale enterprises (SMEs) to enhance cultivation and post-harvesting practices, supported by extension services and a well-trained workforce (Sunadji & Lukas, 2023; Waters et al., 2019).

Even with the annual introduction of these regulatory frameworks, numerous obstacles still exist. The price of wet and dried seaweed continues to fluctuate, driven by market dynamics and global price trends, as well as inconsistencies in the quality of the seaweed produced. These fluctuations negatively impact farmers' income as the low-quality products struggle to meet the competitive standards of both domestic and global markets. The limited availability of skilled and knowledgeable human resources in seaweed cultivation and processing is largely responsible for these issues (Waters et al., 2019). The shortage of trained individuals with expertise in seaweed cultivation practices, particularly at the smallholder level, has led to inconsistent product quality and inefficiencies in the supply chain. In response, the Indonesian government, through the Directorate General of Aquaculture Fisheries of MMAF, has issued technical guidelines to standardize seaweed cultivation, harvesting, and postharvest handling (Sunadji & Lukas, 2023). From the upstream stages of cultivation through processing, these efforts aim to maintain product quality. However, prioritizing the strategic empowerment of seaweed farmers is crucial for these regulations and guidelines to have a meaningful impact. This

includes improving their technical knowledge, access to capital, and involvement in industrial-scale processing. Such empowerment, coupled with industrialization, could address the dual challenges of improving product quality and stabilizing prices, ultimately enhancing the livelihoods of seaweed farmers and strengthening Indonesia's position in the global seaweed industry (Arthatiani et al., 2021; Wardono et al., 2020).

3. Mapping of the SWOT Matrix of Seaweed Industrial Development

To achieve the research objectives, this study concentrated on developing a SWOT matrix as an innovative strategic planning tool tailored to the agri-food sector, with a specific emphasis on the seaweed industry in NTT Province (Rezagama et al., 2021). The analysis considered multiple facets of the seaweed industrial cluster in the region, examining both internal strengths and weaknesses, alongside external opportunities and threats (Ardhana et al., 2021). These dimensions included various factors related to competition, fluctuations in raw material prices, supplier dynamics, and project demands. From this analysis, four primary strategies were identified: S-O (leveraging strengths to capitalize on opportunities), W-O (addressing weaknesses to maximize opportunities), S-T (using strengths to mitigate threats), and W-T (minimizing weaknesses to avoid threats) (Figure 1). Each strategy exhibited distinct characteristics, and their implementation was recommended to be integrated and mutually supportive to ensure effectiveness (Freddy, 2018; Rangkuti, 2015). This comprehensive approach enabled the identification of key areas for improvement and strategic growth within the local seaweed industry cluster in NTT Province.

The initial phase of the SWOT analysis required establishing a clear objective, which could be aimed at optimizing production efficiency, expanding market access, or boosting export capacity. Following this, a comprehensive review of the seaweed industry's current state, relevant market dynamics, and broader industry trends was conducted to frame the analysis. Key strengths were then identified and classified, such as the superior quality of local seaweed varieties and the abundance of natural resources, which serve as essential assets for further development (Citraresmi & Haryati, 2021). On the other hand, weaknesses were pinpointed, including challenges like inadequate technical expertise, suboptimal post-harvesting processes, and a lack of sufficient infrastructure. Opportunities were recognized from both local and international perspectives, including the potential for expanding into new markets, increasing export capacity, and developing value-added products like carrageenan or agar. Threats were also identified, particularly those linked to environmental challenges, fluctuating prices, and global market volatility. The final steps involved prioritizing the SWOT elements to highlight the most critical areas for action. Based on these priorities, strategies were developed to address the identified issues, such as implementing training programs for farmers, improving supply chain logistics, and fostering collaboration with processing and export companies, thereby enhancing the competitiveness and sustainability of the seaweed industry in NTT Province (Ardhana et al., 2021).

4. Mapping of the BMC Model of Seaweed Industrial Development

A grand strategy, representing the prioritized course of action, can be formulated and visualized through the BMC, drawing on the results of the SWOT analysis. To improve the performance of NTT Province's seaweed industry, it is essential to integrate the prioritized strategic options identified through the SWOT analysis within the BMC framework. The BMC for the seaweed business model is depicted in Figure 2, providing a comprehensive visualization of how these strategic elements can be operationalized to drive seaweed industry performance and highlighting the parallel implementation of strategic actions to achieve desired outcomes. Each block within the canvas outlines a distinct strategic priority (Ardhana et al., 2021). These proposed strategies, as shown in Figure 1, guide market segmentation and capitalize on the strengths of the seaweed product offerings. The proposed strategies aim to enhance the performance of the seaweed industry in NTT Province. These proposed strategies are included as follows:

a. Enhancing the quality of dried seaweed to produce Alkali Treated Cottonii (ATC) chips, a high-grade carrageenan raw material derived from raw seaweed with low moisture and impurity levels, targeting the export market.
b. Optimizing ATC chip production to capitalize on domestic and export market opportunities, expanding liquid seaweed products to meet local and regional demand, and opening both domestic and international carrageenan markets.

INTERNAL / EXTERNAL			INTERNAL FACTORS			
			Strengths (S)		Weaknesses (W)	
			S-1	**Abundant Natural Resources**: NTT Province has a vast coastline and favorable environmental conditions for seaweed cultivation.	W-1	**Low Product Quality**: Dried seaweed often fails to meet the quality standards required by the processing industry.
			S-2	**Government Support**: Support from both local and central governments, including regulations like Presidential Decree No. 33 of 2019 for seaweed industry development.	W-2	**Limited Technical Knowledge**: Insufficient expertise in advanced seaweed cultivation and post-harvest handling techniques among farmers.
			S-3	**Emerging Seaweed Processing Clusters**: Development of seaweed cultivation and processing clusters in key regions across NTT.	W-3	**Inconsistent Supply Chain**: Fluctuations in supply due to factors such as poor post-harvest practices and transportation issues.
			S-4	**Established Export Channels**: NTT Province is a key exporter of seaweed to international markets, particularly for the carrageenan industry.	W-4	**Insufficient Infrastructure**: Limited access to adequate processing facilities, particularly in rural and remote areas.
EXTERNAL FACTORS	Opportunities (O)		Strategies S–O		Strategies W–O	
	O-1	**Growing Global Demand**: Increasing demand for seaweed in global markets for food products, ATC chips, bioplastic, cosmetics, and pharmaceuticals.	1	**Leverage Government Support and Natural Resources**: Use government regulations and favorable natural conditions to increase seaweed cultivation, focusing on high-quality production that meets global market demand.	1	**Enhance Farmer Training and Education**: Implement extensive training programs to improve technical knowledge and post-harvest handling techniques, ensuring that the seaweed produced meets international quality standards.
	O-2	**Expansion of Carrageenan Production**: High potential for growth in the carrageenan processing industry, both domestically and internationally.				
	O-3	**Sustainable and Eco-friendly Products**: The global shift towards sustainable and eco-friendly products enhances the attractiveness of seaweed-based industries.	2	**Develop Eco-friendly Product Lines**: Capitalize on growing global demand for sustainable products by expanding the production and export of organic and sustainably farmed seaweed products, using the processing clusters to enhance value addition.	2	**Improve Infrastructure and Technology**: Collaborate with government and private stakeholders to invest in infrastructure, such as modern processing facilities and supply chain management technologies, to ensure consistent quality and increase the capacity for meeting global demand.
	O-4	**Technological Advancements**: Innovations in seaweed cultivation and processing technologies present opportunities for improving efficiency and quality.				
	Threats (T)		Strategies S–T		Strategies W–T	
	T-1	**Price Fluctuations**: The global market for seaweed is highly volatile, leading to frequent price fluctuations that affect farmer incomes.	1	**Diversify Product Markets**: Mitigate the risks of price fluctuations and competition by diversifying the seaweed product offerings, including liquid seaweed, bioplastics, and health supplements, to tap into multiple market segments both domestically and internationally.	1	**Improve Quality Control Systems**: Address the issue of low-quality production and price volatility by implementing stringent quality control measures at all stages of the seaweed value chain, from cultivation to processing and export.
	T-2	**Competition from Other Regions**: Increased competition from other seaweed-producing regions both domestically and globally.				
	T-3	**Climate Change**: Environmental changes, including rising sea temperatures and unpredictable weather patterns, could negatively impact seaweed yields.	2	**Develop Climate-resilient Cultivation Techniques**: Leverage government support to introduce resilient seaweed varieties and cultivation practices designed to adapt to climate change and minimize environmental risks.	2	**Collaborate on Policy Advocacy**: Work with industry stakeholders to influence policy decisions that favor the growth of the seaweed industry (sustainable practices incentives, export subsidies, and protective measures against market volatility).
	T-4	**Regulatory Changes**: Shifting policies or stricter regulations, both domestically and internationally, could pose challenges to the industry's growth.	3	**Focus on Regional Branding**: Promote NTT seaweed through regional branding efforts as a premium and sustainably sourced product, differentiating it from competitors and creating a competitive advantage in the global market.	3	**Establish Risk Mitigation Frameworks**: Create frameworks to manage risks posed by climate change and market competition, including insurance schemes for farmers, diversification of income sources, and better access to market information to reduce vulnerability to external shocks.

Figure 1. Mapping of the SWOT matrix of seaweed industrial development in NTT Province.

5. Weights and Priorities of Hierarchical Alternative Strategy Level

The improvement of infrastructure and technology strategy was observed as the highest weight value at the alternative strategy hierarchy indicated the main priority of the seaweed industry development in NTT Province. The weight value and priority of alternative strategies are presented in Table 1.

Table 1. Weight and priority of the alternative strategies.

No.	Factor	Alternative Strategy	Weight	Priority
1.	S-O	Leverage Government Support and Natural Resources: Use government regulations and favorable natural conditions to increase seaweed cultivation, focusing on high-quality production that meets global market demand	0.081	10
2.		Develop Eco-friendly Product Lines: Capitalize on growing global demand for sustainable products by expanding the production and export of organic and sustainably farmed seaweed products, using the processing clusters to enhance value addition	0.095	6
3.	W-O	Enhance Farmer Training and Education: Implement extensive training programs to improve technical knowledge and post-harvest handling techniques, ensuring that the seaweed produced meets international quality standards	0.120	2
4.		Improve Infrastructure and Technology: Collaborate with government and private stakeholders to invest in infrastructure, such as modern processing facilities and supply chain management technologies, to ensure consistent quality and increase the capacity for meeting global demand	0.122	1
5.	S-T	Diversify Product Markets: Mitigate the risks of price fluctuations and competition by diversifying the seaweed product offerings, including liquid seaweed, bioplastics, and health supplements, to tap into multiple market segments both domestically and internationally	0.106	4
6.		Develop Climate-resilient Cultivation Techniques: Leverage government support to introduce resilient seaweed varieties and cultivation practices designed to adapt to climate change and minimize environmental risks.	0.087	8
7.		Focus on Regional Branding: Promote NTT Province' seaweed through regional branding efforts as a premium and sustainably sourced product, differentiating it from competitors and creating a competitive advantage in the global market	0.085	9
8.	W-T	Improve Quality Control Systems: Address the issue of low-quality production and price volatility by implementing stringent quality control measures at all stages of the seaweed value chain, from cultivation to processing and export	0.112	3
9.		Collaborate on Policy Advocacy: Work with industry stakeholders to influence policy decisions that favor the growth of the seaweed industry (sustainable practices incentives, export subsidies, and protective measures against market volatility)	0.093	7
10.		Establish Risk Mitigation Frameworks: Create frameworks to manage risks posed by climate change and market competition, including insurance schemes for farmers, diversification of income sources, and better access to market information to reduce vulnerability to external shocks	0.099	5

The AHP analysis revealed strategic priorities for developing the seaweed industry in NTT Province, with a focus on improving infrastructure, technology, and human resource capacity. The highest priority, with a weight of 0.122, was given to the W-O (Weaknesses-Opportunities) strategy (Table 1), which emphasized the need for innovation and infrastructure development through collaboration between government and private stakeholders. This high ranking reflects the industry's current limitations, particularly in processing capabilities, technology adoption, and post-harvest handling, which are critical to increasing the industry's global competitiveness. Seaweed industry faces challenges such as inadequate facilities, poor quality control, and inefficient supply chains, making infrastructure improvement essential to meet global standards. The second highest priority, with a weight of 0.120, focused on improving technical knowledge and post-harvest handling techniques (Table 1). In fact, another key priority centered on empowering local farmers (AIP-PRISMA, 2016; Muhtar & Makkulawu, 2023). The importance of this strategy stems from the significant role local farmers play within industry. Most seaweed cultivation in NTT Province is conducted by small-scale farmers with limited access to education and technology, leading to inconsistent quality. Therefore, investing in farmer training and education is vital to enhancing their capacity to produce seaweed that meets international quality standards, directly addressing the industry's weaknesses. This training was considered vital to ensure that seaweed produced in the region could meet international quality standards, thus improving its competitiveness in global markets (Muhtar & Makkulawu, 2023). Strengthening the capabilities of farmers through targeted education and skills development was seen as a fundamental step in enhancing the overall productivity and quality of the seaweed industry.

In contrast, strategies related to leveraging government support and natural resources received lower weightings (0.081), reflecting the relatively strong position of natural environment and regulatory support for seaweed cultivation. These factors were not seen as immediate bottlenecks compared to the more pressing issues of infrastructure and human capital. While favorable natural conditions are an asset, the real challenge lies in converting these resources into higher-value products through better processing and supply chain systems. The weightings in the AHP analysis reflect the current industry dynamics by highlighting the critical need for modernization and capacity-building to overcome existing weaknesses. With global demand for seaweed products increasing, particularly for value-added products such as carrageenan and ATC chips, the industry must prioritize upgrading facilities and training local farmers to maintain competitiveness. The focus on collaboration between public and private sectors underlines the necessity for public-private partnerships to drive these developments, given the high costs and technical expertise required. These findings illustrate that the industry's primary weaknesses—outdated infrastructure, inadequate technology, and poor farmer education—must be addressed to fully capitalize on natural advantages and growing global demand for seaweed products. Addressing these weaknesses through targeted investments and capacity-building will create a more resilient and competitive capability.

However, it was suggested that the emphasis should be on producing high-quality seaweed that aligns with global market demands. Although this strategy was ranked lower, it still held significant importance in ensuring the sustainability of the seaweed industry, particularly in increasing the scale of cultivation while maintaining quality. To address existing knowledge gaps in the seaweed industry's development and the broader food systems in NTT Province, there was a strong recommendation for conducting extensive research. This research should focus on improving seaweed handling and processing methods, promoting organizational changes, and enhancing the skills of farmers and other stakeholders involved in the seaweed value chain (Snethlage et al., 2023). It was recognized that without these advancements, the seaweed industry in NTT Province would struggle to compete effectively on the international stage. Therefore, the development strategy for the seaweed industry necessitated a multi-faceted approach. By combining infrastructural improvements, technological innovation, farmer education, and strategic government support, the industry could enhance both its productivity and global competitiveness (Hailu, 2023).

The development of the BMC for the seaweed industry began with integrating strengths-opportunities (S-O) and weaknesses-threats (W-T) strategies into the key partners element. Key partners represent the critical relationships a company maintains with other entities, such as suppliers, manufacturers, regulators, or advisors, which are essential for operational success. In this study, the BMC's key partners element was enhanced by incorporating strategies that leverage government support and natural resources, as well as collaborating on policy advocacy, as identified through the SWOT analysis. This collaboration aimed to ensure a more sustainable and supportive ecosystem for seaweed cultivation and processing. The key activities element of the BMC was also enriched by integrating specific strategies from the SWOT analysis. These included the development of eco-friendly product lines (S-T), aimed at meeting increasing consumer demand for sustainable products while mitigating environmental risks. Additionally, improving infrastructure and technology (W-O) was emphasized to enhance production efficiency and scalability. Diversification of product markets (S-T), by providing ATC chips, liquid seaweed, agar, agarose, carrageenan, alginate, and bioplastic raw material to various potential markets, was identified as another key activity, allowing businesses to engage into new market segments and reduce reliance on limited markets.

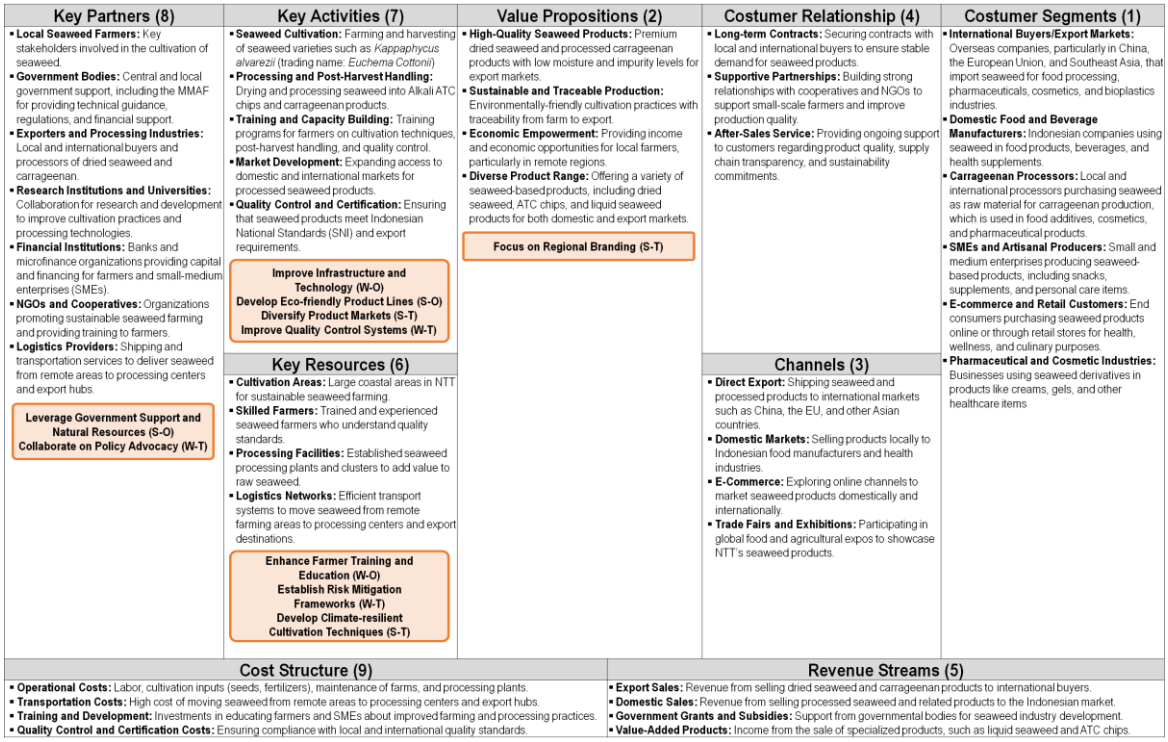

Figure 2. Mapping of the BMC model of seaweed industrial development in NTT province after being integrated with SWOT analysis.

Lastly, the improvement of quality control systems (W-T) was prioritized to address quality issues, ensuring that products meet international standards and remain competitive in the global market (as shown in Table 1 and Figure 1). One of the critical factors for success in advancing the seaweed industry within the globalized market was maintaining a high-quality supply chain. The quality of seaweed, a vital indicator for agri-food products in the export market, depended on three primary factors: cultivation practices, the timing of the harvest, and the drying process. Additionally, variations in cultivation locations significantly impacted the final product's quality (Darmawan et al., 2020). Seed selection and supply were also crucial, with an emphasis on ensuring that seeds were affordable, readily available, scalable, and sustainable. These factors collectively played a pivotal role in ensuring the raw material quality necessary for effective production. The strategies identified through the integration of SWOT analysis with the BMC model can serve as a crucial foundation for informing government policy to support sustainable seaweed production and address industry challenges. For example, the W-O strategy, which emphasizes improving infrastructure and technology through public-private collaboration, highlights the need for policies that encourage investment in modern processing facilities, supply chain management, and technological advancements.

By prioritizing support for infrastructure upgrades, governments can facilitate better quality control, reduce post-harvest losses, and enhance competitiveness in global markets. Furthermore, the S-T strategies, which focus on diversifying product markets and developing eco-friendly products, align with policies promoting sustainable

production practices and green technology adoption. Policymakers can also address weaknesses, such as limited technical knowledge, by designing training and educational programs to improve farmer skills, particularly in post-harvest handling and processing. These integrated strategies provide a roadmap for governments to promote innovation, ensure industry resilience, and foster sustainable economic growth in the seaweed sector.

D. CONCLUSION

Through the combination of SWOT-BMC integrated through a help of AHP approach, the proposed strategies of seaweed industrial development to support strategic planning in the agri-food sector in NTT Province are leveraging government support and natural resources (S-O) and collaborating on policy advocacy (W-T) to key partners element, improving infrastructure and technology (W-O), improving quality control systems (W-T), diversifying product markets (S-T), and developing eco-friendly product lines (S-O) to key activities element, and supplementing enhance farmer training and education (W-O), establish risk mitigation frameworks (W-T), and develop climate-resilient cultivation technology (S-T) to key resources, and adding focus on regional branding (S-T) to value preposition. Based on the AHP analysis, the highest strategy priority was to leverage government support and natural resources, while the lowest priority was to improve infrastructure and technology. Key findings revealed that enhancing infrastructure and technology, diversifying markets, and improving quality control were vital for seaweed industry growth. In this case, collaboration between the government and private sectors is essential. Strategic investments in modern processing technologies, farmer capacity-building programs, and eco-friendly practices could accelerate the development of the seaweed industry. Policymakers should create supportive frameworks to boost competitiveness and sustainability in global markets.

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