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Risk Assessment of Sustainable Pineapple Supply Chain Management

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Abstract

The main objective of this study is to assess risks in the pineapple supply chain and introduce performance indicators for flexibility in Thailand's pineapple supply chain. A risk mitigation strategy was specifically created based on the problems faced by pineapple farmers, from the cultivation process to the distribution process. The questionnaire was meticulously designed to collect data from three sample groups: experts to assess the consequence dimension, and pineapple farmers in Prachuap Khiri Khan province to assess the likelihood dimension, divided into pineapple farmers implemented with and without GAP. The output of this research yielded eleven strategies, including three proactive strategies, three defensive strategies, two remedial strategies, and three reactive strategies. This study not only suggests risk mitigation strategies for sustainable pineapple supply chain management but also presents the outcome of risk mitigation through appropriate strategies that will make pineapple farmers more competitive and sustainable.

Keywords : Sustainable supply chain management; Risk mitigation strategy; Factory pineapple; Competitiveness

Introduction

The canned pineapple processing industry in Thailand serves as a link between agriculture and industry, adding significant value to agricultural raw materials. Prachuap Khiri Khan province leads in Smooth Cayenne pineapple production, cultivation, and harvested areas. Statistical data from 2021 indicated an increase in pineapple planting areas compared to the previous year [1–2]. In 2022, Thailand exported 265,667 tons of canned pineapple, valued at USD 301 million. Furthermore, both the value and volume expanded compared to the previous year. The export report on canned pineapple from the Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, revealed a trend of increasing value and volume based on data from 2019 to 2022 [3]. The price of pineapple increased by 14.61% in 2022 compared to the previous year, as the production volume was insufficient to meet global market demand [4]. This is an important issue for Thailand in creating sustainable added value for Smooth Cayenne pineapple, also known as 'factory pineapple' in the canned pineapple processing industry. In this endeavor, Thailand's canned pineapple processing industry aims to outperform competitors, including the Philippines and Indonesia [5]. These countries emphasize agricultural production by large companies, allowing for continuous production. Consequently, the Philippines and Indonesia can offer lower export prices compared to Thailand due to the efficiency of large-scale farming in controlling production costs. Additionally, factory pineapple

production decreased by 14.12% in the second quarter of 2023 [6].

The Ministry of Agriculture and Cooperatives, the Ministry of Industry, the Ministry of Commerce, and related agencies collaborate to enhance pineapple production efficiency in Thailand by supporting large-scale pineapple cultivation through the Pineapple Strategy 2017-2026. The strategic goal is to maintain leadership as the world's number one pineapple exporter by achieving price stabilization, adhering to pineapple product quality standards, and fostering sustainability in the careers of farmers and pineapple processing plants. These outcomes result from implementing four key strategies: 1) production; 2) processing; 3) marketing; and 4) management [7].

The researcher acknowledges the critical role of Thailand's pineapple supply chain, recognizing it as a major agricultural product in Thailand's exports and adding value to the country's agricultural economy. This research focuses on risk assessment in the factory pineapple supply chain in Prachuap Khiri Khan to analyze the environment and potential. Additionally, it aims to formulate strategies to enhance the strengths of the agricultural sector, specifically in the upstream segment of the factory pineapple supply chain. These efforts are geared towards increasing income for the country and driving growth in the agricultural economy.

Methodology

1. Investigating and collecting information in each process

The framework of this study involves the cultivation process to the post-harvest process, consisting of five main stages, i.e., 1) preparation of the field for planting or preparing the soil; 2) preparation of planted shoots; 3) planting, care, and forcing to fruit; 4) harvesting and transportation of pineapples; and 5) sales of goods to processing plants. Farmers face risks at every stage, ranging from minor to severe. The risk of the cultivation process for distribution consists of nineteen risks [8-9] as follows: 1) poor-quality planting plots; 2) errors in forecasting and planting planning; 3) low quality of factors in production; 4) unstable selection of production factors; 5) lack of agricultural tools and equipment; 6) unbalanced efficiency and effectiveness; 7) lack of support for the production process development; 8) poor quality control; 9) severe drought or inadequate agricultural water supply; 10) plant pests; 11) insect pests; 12) ripeness less than 25%; 13) nitrate value more than 25 mg/kg; 14) lack of availability of transport vehicles; 15) unreliable transportation; 16) shortage of labor in the production process; 17) low labor efficiency; 18) uncertain changes in purchase price; and 19) limited product distribution channel.

2. Determination of the risk assessment matrix

The risk assessment is conducted using a risk matrix, which consists of two dimensions, i.e., 1) likelihood, probability, or frequency of facing risks; and 2) consequence, impact, or severity when those risks are faced [10]. The risk assessment matrix in this study utilizes a 3x3 structure (risk assessment matrix 3 by 3), incorporating three levels in each dimension. Additionally, the risk assessment score interpretation for each dimension involves a cross-multiply of all levels in both dimensions [9], as shown in Table 1.

Risk assessment scores 1 and 2 represent slight and acceptable risks, respectively, while scores of 3 and 4 indicate medium and moderate risks. These risks can impact a large population or risk group, leading to disruptions in normal activities and services. The risk mitigation approach involves additional control measures and requires a moderate level of resources. A major risk with a score of 6 is a transmitted risk that has a major impact on small populations or risk groups, causing major disruptions to normal activities and services. The mitigation approach involves implementing a large number of additional control measures and requiring some significant resources. Lastly, an unacceptable risk with a score of 9 has severe impacts on the population or a large number of high-risk groups, causing severe disruption to normal activities and services. The mitigation approach involves implementing several additional control measures and requiring the most significant resources.

Table 1 Risk assessment matrix

		Consequence		
		Slightly harmful (1 point)	**Harmful** (2 points)	**Extremely harmful** (3 points)
Likelihood	**likely** (3 points)	Medium risk (Score 3)	Major risk (Score 6)	Unacceptable risk (Score 9)
	Unlikely (2 points)	Acceptable risk (Score 2)	Moderate risk (Score 4)	Major risk (Score 6)
	Highly unlikely (1 point)	Slight risk (Score 1)	Acceptable risk (Score 2)	Medium risk (Score 3)

The researcher assesses the risk scores from three sample sizes, categorizing them into three groups based on appropriate numbers. The consequence dimension represents the average score of 10 experts, while the likelihood dimension represents the average score of 118 pineapple farmers. In this study, pineapple farmers were divided into two groups: Group 1 comprises pineapple farmers who implemented GAP (good agricultural practices), totaling 8 persons; and Group 2 consists of pineapple farmers who did not implement GAP, totaling 110 persons. The sample size of pineapple farmers in Group 2 was calculated from the total of 13,670 pineapple farmers in Prachuap Khiri Khan at a 90% confidence level, combined with a 10% tolerance. The risk assessment can indicate critical or unacceptable risks faced by pineapple farmers [11].

3. Determination of the flexibility performance metric

Natanaree Sooksaksun, Kiadtikun Wavnum, Jitraporn Thepklang, and Sasimaporn Seehaworg (2023) discussed the performance metrics of the Supply Chain Operations Reference (SCOR) model, which include reliability, responsiveness, agility, cost, and asset management efficiency [12]. Moreover, Ertugrul Ayyildiz and Alev Taskin Gumus (2021) delved into the SCOR 4.0 model and its performance metrics, encompassing seven aspects: 1) reliability, such as quantity, accuracy, and quality; 2) flexibility, covering production, delivery, and risk; 3) responsiveness, including cycle time and quantity supplied; 4) cost, involving production, transportation, and maintenance; 5) assets, such as working capital, cash-to-cash cycle, and fixed assets; 6) digital technology, encompassing ability, methods, and systems; and 7) information systems, covering integration and content. Additionally, they explained flexibility as the agility to respond to market changes to gain and/or maintain a competitive advantage in a supply chain [13]. This involves addressing errors in inventory management, planning, distribution management, forecasting, etc. [14].

Edgar Ramos, Phillip S. Coles, Melissa Chavez, and Benjamin Hazen (2022) discussed the flexibility metric, which belongs to cluster one in the fuzzy MICMAC analysis. This metric is characterized by not directly influencing the system but being highly unstable, impacting supply chain performance. Although it represents one of the least critical factors, it requires relative attention [14]. The flexibility performance metric in this study is derived from nineteen identified risk issues based on information obtained from the risk assessment [9]. These metrics contribute to the performance evaluation of pineapple supply chain management, enabling pineapple farmers to analyze and assess risks within the supply chain.

4. Environment and potential analysis

The SWOT analysis, or environment and potential analysis, is a tool for analyzing internal and external factors that impact the achievement of an organization's, agency's, or development's goals. Internal factors, or potential factors, involve factors dependent on performance. These

factors can be controlled and are often associated with strengths and weaknesses. Examples of internal factors include marketing, input management, personnel, financial factors, etc. An organization, agency, or any development that can perform better than a competitor is considered a strength. However, if an organization has a lower process than competitors, it is considered a weakness that needs improvement.

External factors, or environmental factors, are factors that the organization cannot control or manage. They are often associated with opportunities and obstacles. Examples of external factors include values, labor laws, the economy, etc. These factors may affect the operation in both positive and negative ways. Christine Namugenyi, Shastri L. Nimmagadda, and Torsten Reiners (2019) summarized strengths in the agriculture business that can add value to the agriculture industry, including farming practices, new farming technologies, automation, efficient use of available resources, quality seeds, chemical fertilizers, government subsidies, encouraging organic farming, and sustainable water and energy resources.

Regarding weaknesses that may lead to failure, these include limited access to loans, non-availability of government subsidies, failure to obtain favorable selling rates, poor-quality seeds, interrupted supply of fertilizers and raw materials needed in farming, frequent power outages, and poor-quality farming practices [15].

The SWOT analysis leads to strategy determination. Strength is an operation that drives achievement toward the goal, while weakness is an operation that poses a disadvantage to reaching the goal. Opportunities and threats involve the external environment. An opportunity is an encouraging environment to achieve the goal, while a threat is an environment that could hinder the goal.

5. The development of risk mitigation strategies

The strategy creation, or TOWS matrix, involves the analysis of the relationship between internal and external pair issues, which are SO, ST, WO, and WT. SO is a proactive strategy that takes advantage of internal strengths and external opportunities. ST is a defensive strategy that mitigates external barriers through internal strengths. WO is a remedial strategy that corrects internal weaknesses by considering positive external opportunities. WT is a reactive strategy that reduces the damage caused by internal weaknesses and external obstacles [16].

Critical or unacceptable risks identified through risk assessments are considered weaknesses (Weaknesses: W) if they stem from the actions of the farmers themselves. Environmental factors that create risks in conducting business are regarded as obstacles (Threats: T) if they result from the external environment, which is beyond the control of farmers. If a risk is small or acceptable based on the risk assessment, it is considered a strength (Strength: S) of farmers. Moreover, if it arises from assistance from the external environment, it is seen as an opportunity (Opportunity: O). Furthermore, the researcher plans to develop feasible strategies to establish sustainable pineapple supply chain management to enhance the efficiency of pineapple production in Thailand. This will lead to quality products and can reduce manufacturing costs.

The overall flowchart of this research is shown in Figure 1.

Results and Discussion

1. The pineapple supply chain in Prachuap Khiri Khan, Thailand

The pineapple supply chain is depicted in Figure 2, providing an overview from upstream to downstream. Prachuap Khiri Khan Province serves as the primary cultivation area for Smooth Cayenne pineapples (known as 'factory pineapple') in Thailand, and it is the main location for processing canned pineapples for export. This study focuses on identifying risks upstream in the supply chain, starting from the cultivation process to the post-harvest process for selling fresh pineapples to the canned pineapple processing factory. It serves as the main distribution channel for Prachuap Khiri Khan pineapple farmers, playing a crucial role in Thailand's export of canned pineapples.

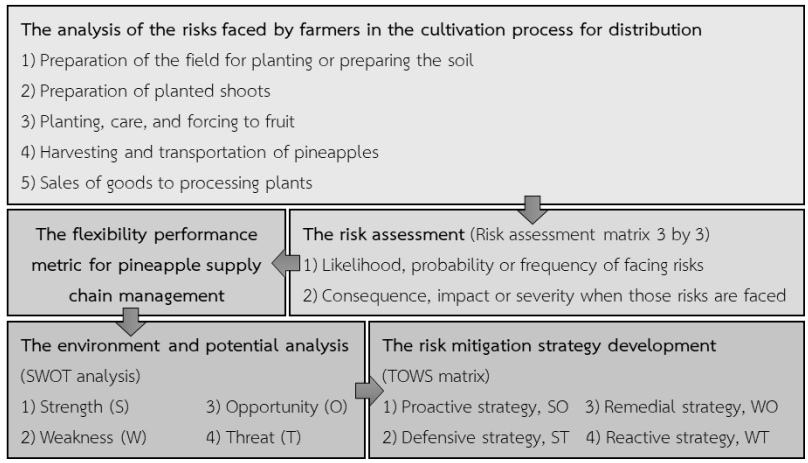

Figure 1 The overall flowchart of this research

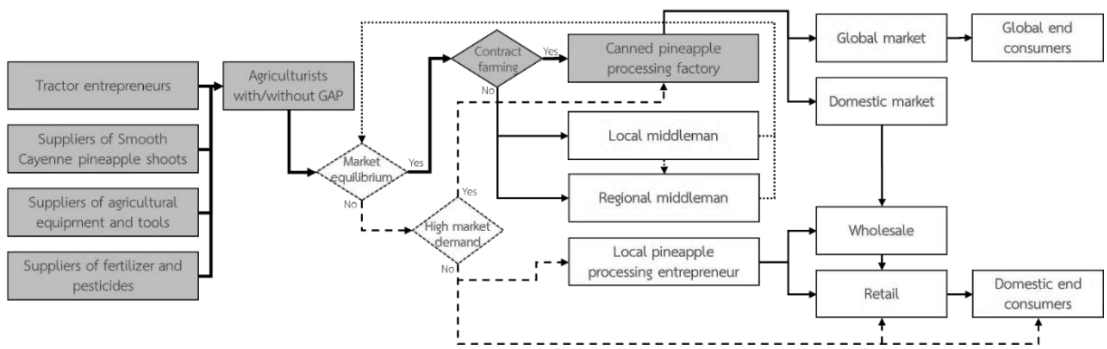

Figure 2 The pineapple supply chain in Prachuap Khiri Khan, Thailand [11]

2. The result of the risk assessment

The risk assessment of nineteen potential risks that may occur to Prachuap Khiri Khan farmers in the pineapple supply chain includes: 1) poor-quality planting plots; 2) errors in forecasting and planting planning; 3) low quality of factors in production; 4) unstable selection of production factors; 5) lack of agricultural tools and equipment; 6) unbalanced efficiency and effectiveness; 7) lack of support for the production process development; 8) poor-quality control; 9) severe drought or inadequate agricultural water supply; 10) plant pests; 11) insect pests; 12) ripeness less than 25%; 13) nitrate value more than 25 mg/kg; 14) lack of availability of transport vehicles; 15) unreliable transportation; 16) shortage of labor in the production process; 17) low labor efficiency; 18) uncertain changes in purchase price; and 19) limited product distribution channel [9, 11].

The study found that risk number 15 is a slight risk, scoring the lowest in the risk assessment. This slight risk includes: 1) farmers not moving their products within two days after harvesting, resulting in fungi on the top and bottom of pineapples; and 2) farmers not properly arranging pineapples on the truck, causing pineapple damage during transportation. Risk numbers 5 (lack of agricultural tools and equipment) and 14 (lack of availability of transport vehicles) are the second-lowest risks and are considered acceptable. Additionally, risk numbers 1, 3-4, 6, 8, 10-13, 17, and 19 with a score of 3 or 4 points are classified as medium or moderate risks. Moreover, the study identifies a total of five major risks, including risks numbers 2, 7, 9, 16, and 18, as shown in Table 2. The results of the risk assessment for the five major risks are consistent across both farmer groups. These major risks can impact yields and

may cause significant disruptions to normal activities. Therefore, there is a need for important resources and the implementation of numerous additional control measures to standardize and decrease these risks.

The researcher can elaborate on the five major risks presented in Table 2 by highlighting two interesting observations. Pineapple farmers implemented GAP (good agricultural practices) to effectively mitigate internal risks. Consequently, the risk assessment for risk numbers 2 (errors in forecasting and planting planning), 9 (severe drought or inadequate agricultural water supply), and 16 (shortage of labor in the production process) yielded lower scores compared to pineapple farmers not implementing GAP. In contrast, pineapple farmers who implemented GAP demonstrated increased awareness of external risks. This is evident in the risk assessment for risk numbers 7 (lack of support for the production process development) and 18 (uncertain changes in purchase price), which yielded higher risk scores compared to pineapple farmers not implementing GAP.

Additionally, the researcher can present statistical analyses of three datasets, including 1) a consequence dataset; 2) a likelihood dataset from farmers with GAP; and 3) a likelihood dataset from farmers without GAP. Dataset 1 showed the mean and standard deviation of the risk score for impact or severity when those risks are faced as 2.13 and 0.46, respectively. Datasets 2 and 3 showed the mean and standard deviation of the risk score for the probability or frequency of facing risks as 1.66 and 0.42 for dataset 2, and 1.72 and 0.37 for dataset 3. Moreover, the researcher presented the distribution visualization of three datasets through the normal distribution curve and the error bar, as shown in Figure 3.

Table 2 The result of the risk assessment

Risks	Risk assessment (Evaluation score = Avg. likelihood x Avg. consequence)					Risk assessment		The result interpretation of risk assessment	
	Average likelihood		Average consequence	Evaluation score					
	G1	G2		G1	G2	G1	G2	G1	G2
1) Poor-quality planting plots	1.88	2.18	2.00	3.76	4.36	4	4	Moderate risk	Moderate risk
2) Errors in forecasting and planting planning	1.75	1.95	2.40	4.20	4.68	4	5	Moderate risk	Moderate-Major risk
3) Low quality of factors in production	1.75	1.56	2.00	3.50	3.12	4	3	Moderate risk	Medium risk
4) Unstable selection of production factors	1.50	1.65	1.80	2.70	2.97	3	3	Medium risk	Medium risk
5) Lack of agricultural tools and equipment	1.13	1.17	1.40	1.58	1.64	2	2	Acceptable risk	Acceptable risk
6) Unbalanced efficiency and effectiveness	1.63	1.64	2.20	3.59	3.61	4	4	Moderate risk	Moderate risk
7) Lack of support for the production process development	2.50	2.21	2.60	6.50	5.75	7	6	Major-Unacceptable risk	Major risk
8) Poor-quality control	1.50	1.97	2.00	3.00	3.94	3	4	Medium risk	Moderate risk
9) Severe drought or inadequate agricultural water supply	1.88	2.22	2.60	4.89	5.77	5	6	Moderate-Major risk	Major risk
10) Plant pests	1.50	1.61	2.60	3.90	4.19	4	4	Moderate risk	Moderate risk
11) Insect pests	1.63	1.54	2.20	3.59	3.39	4	3	Moderate risk	Medium risk
12) Ripeness less than 25%	1.25	1.51	1.80	2.25	2.72	2	3	Acceptable risk	Medium risk
13) Nitrate value more than 25 mg/kg	1.13	1.30	2.40	2.71	3.12	3	3	Medium risk	Medium risk
14) Lack of availability of transport vehicles	1.13	1.22	1.40	1.58	1.71	2	2	Acceptable risk	Acceptable risk
15) Unreliable transportation	1.13	1.20	1.20	1.36	1.44	1	1	Slight risk	Slight risk
16) Shortage of labor in the production process	2.00	2.42	2.40	4.80	5.81	5	6	Moderate-Major risk	Major risk
17) Low labor efficiency	1.88	1.55	2.00	3.76	3.10	4	3	Moderate risk	Medium risk
18) Uncertain changes in purchase price	2.63	2.08	3.00	7.89	6.24	8	6	Major-Unacceptable risk	Major risk
19) Limited product distribution channel	1.75	1.74	2.40	4.20	4.18	4	4	Moderate risk	Moderate risk

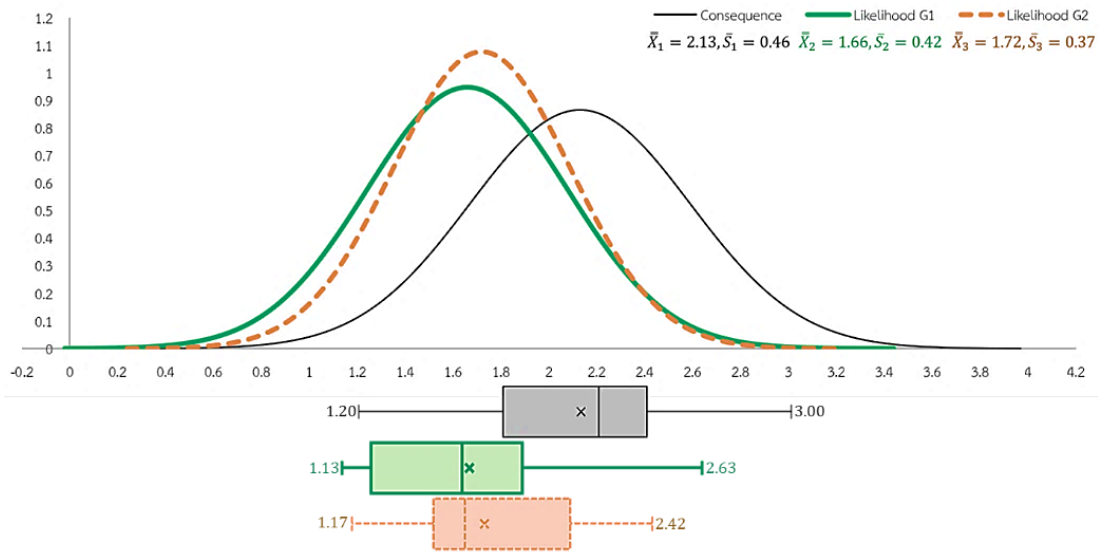

Figure 3 The distribution visualization of three datasets

3. The flexibility performance metric in the pineapple supply chain

The researcher can explain the risk weight derived from the average consequence of each risk as determined by 10 experts in Table 2. The calculated risk weight is shown in Figure 4. Additionally, the average likelihood in Table 2 from pineapple farmers implemented with and without GAP is converted to integer values of 1, as indicated in Table 3. The risk value above was calculated by using the risk weight, which is the weighted risk value for each risk. Subsequently, the flexibility performance of pineapple farmers is determined by subtracting the total risk percentage from 100%. The flexibility performance of pineapple farmers implemented with GAP is 42.42%, and pineapple farmers implemented without GAP is 40.81%, as shown in Table 3.

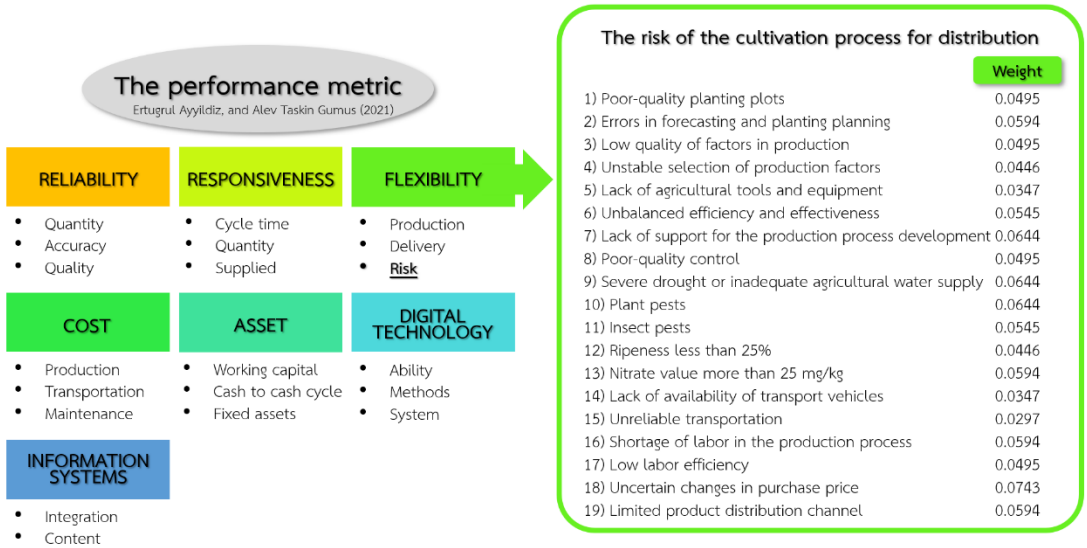

Figure 4 The risk weight for calculating the flexibility performance in each metric

4. The result of the environment and potential analysis

The interpretation of the nineteen risk assessments leads to an environment and potential analysis involving three strengths, two weaknesses, and three threats. Moreover, the researcher studies and gathers opportunities to help and support the Thailand pineapple supply chain from the Agricultural and Cooperative Development Plan of Prachuap Khiri Khan Province (2023-2027) as follows: Opportunity (O) is defined by three issues, i.e., 1) O1: advancements in new technology; 2) O2: government policies supporting agriculture across administrative tiers; and 3) O3: growing global demand for agricultural products [17]. Threat (T) involves three issues, i.e., 1) T1: water resource insufficiency in agricultural land due to a severe drought; 2) T2: labor shortages encountered by farmers in the production process; and 3) T3: price volatility confronted by farmers. Strength (S) consists of three issues, i.e., 1) S1: proficiency and knowledge of farmers in safely transporting and distributing agricultural products; 2) S2:

Table 3 The flexibility performance in each metric of pineapple farmers in Prachuap Khiri Khan, Thailand

Risks	Weight	Risk value		Weighted risk value	
		G1	G2	G1	G2
1) Poor-quality planting plots	0.0495	0.6267	0.7267	0.0310	0.0360
2) Errors in forecasting and planting planning	0.0594	0.5833	0.6500	0.0346	0.0386
3) Low quality of factors in production	0.0495	0.5833	0.5200	0.0289	0.0257
4) Unstable selection of production factors	0.0446	0.5000	0.5500	0.0223	0.0245
5) Lack of agricultural tools and equipment	0.0347	0.3767	0.3900	0.0131	0.0135
6) Unbalanced efficiency and effectiveness	0.0545	0.5433	0.5467	0.0296	0.0298
7) Lack of support for the production process development	0.0644	0.8333	0.7367	0.0537	0.0474
8) Poor-quality control	0.0495	0.5000	0.6567	0.0248	0.0325
9) Severe drought or inadequate agricultural water supply	0.0644	0.6267	0.7400	0.0404	0.0477
10) Plant pests	0.0644	0.5000	0.5367	0.0322	0.0346
11) Insect pests	0.0545	0.5433	0.5133	0.0296	0.0280
12) Ripeness less than 25%	0.0446	0.4167	0.5033	0.0186	0.0224
13) Nitrate value more than 25 mg/kg	0.0594	0.3767	0.4333	0.0224	0.0257
14) Lack of availability of transport vehicles	0.0347	0.3767	0.4067	0.0131	0.0141
15) Unreliable transportation	0.0297	0.3767	0.4000	0.0112	0.0119
16) Shortage of labor in the production process	0.0594	0.6667	0.8067	0.0396	0.0479
17) Low labor efficiency	0.0495	0.6267	0.5167	0.0310	0.0256
18) Uncertain changes in purchase price	0.0743	0.8767	0.6933	0.0651	0.0515
19) Limited product distribution channel	0.0594	0.5833	0.5800	0.0346	0.0345
				0.5758	0.5919
100% performance minus the total risk percentage =				57.58%	59.19%
The flexibility performance of pineapple farmers in Prachuap Khiri Khan, Thailand				**42.42%**	**40.81%**

5. Sustainable development of Thailand's pineapple supply chain

The strategy analysis aims to enhance the performance of Thailand's pineapple production, aiming to produce high-quality products and reduce production costs. The result of this analysis leads to the development of eleven sustainable strategies for preparedness of farmers' vehicles for agricultural product transportation and distribution; and 3) S3: adequate agricultural tools and equipment possessed by farmers for pineapple cultivation. Weakness (W) includes two issues, i.e., 1) W1: lack of support for advancing the production process through the adoption of innovations for enhanced production and reduced costs by farmers; and 2) W2: a deficiency in statistical market data hinders precise forecasting and strategic planning for farmers. Thailand's pineapple supply chain. Three strength issues and three opportunity

issues result in three SO (Strength-Opportunity) strategies. The ST strategy is analyzed for defense against the relationship between strengths and threats. Thus, the researcher creates three ST (Strength-Threat) strategies. The WO strategy is analyzed for remediation based on the relationship between opportunities and weaknesses, and the researcher can create two WO (Weaknesses-Opportunity) strategies. Last, the WT strategy is analyzed for reactivity from the relationship between weaknesses and threats, from which the researcher can create three WT (Weaknesses-Threats) strategies, as explained in Table 4. Specific aspects of this study demonstrate congruence with the research conducted by Christine Namugenyi, et al. (2019) and Radasa Netsangsee (2022), such as new farming technologies, automation, efficient use of available resources, quality seeds, chemical fertilizers, government subsidies, encouraging organic farming, sustainable water and energy resources, training on pineapple quality development, marketing channel development, etc. [15, 18].

Table 4 Sustainable strategy development

Strategy		Strategy detail
Three SO proactive strategies	S1O2	The design and development of equipment for loading and unloading aims to enhance the efficient movement of agricultural products within fields. This equipment streamlines the loading and unloading processes of transport vehicles, resulting in reduced time requirements and the elimination of unnecessary procedures. Consequently, it contributes to the reduction of potential damage to agricultural products during transportation.
	S2O1	The queue management system for direct delivery from the farm to the pineapple processing factory can be enhanced through technology. This approach not only provides farmers with real-time information about their position in the queue but also leads to a significant reduction in waiting times.
	S3O3	New technology and innovation (e.g., drones, automatic watering systems, etc.) can save time in the farmer's cultivation process, bring about greater accuracy, and lower production costs compared to human labor. Additionally, it can enhance safety for farmers when using agricultural chemicals.
Three ST defensive strategies	S1T3	The challenge of uncertain purchase prices. A strategy involves promoting and distributing fresh pineapples through various initiatives, such as marketing campaigns and fruit festivals, as well as seeking collaboration to encourage fresh pineapple consumption. This approach offers an initial solution to mitigate the impact of price fluctuations.
Three ST defensive strategies	S2T1	An initial solution to mitigate the effects of agricultural water scarcity caused by drought is to use vehicles for direct transportation from nearby water resources to plantation areas. This approach helps safeguard against adverse effects resulting from insufficient agricultural water for farming.
	S3T2	The challenge of labor shortages requires a strategic approach, such as operating small farms collaboratively to enable collective support in hiring seasonal foreign laborers, facilitated by government programs.
Two WO remedial strategies	W1O2, W1O3	The government must establish a knowledge-sharing center to instruct on new technology and innovation to support the development of the farmers' production process. This will lead to lower production costs while maintaining or improving the quality of pineapples.
	W2O1	Farmers should incorporate additional distribution channels, particularly during periods of oversupply for both fresh and processed pineapple products, within small and medium-sized enterprises (SMEs) by utilizing online platforms. These platforms enable direct connections with consumers, facilitating more efficient distribution.
Three WT reactive strategies	W1T1	The challenge of coping with severe drought and the resultant water shortage on farmland requires farmers to apply modern technology and innovative techniques in their cultivation practices. This approach enables the efficient management of agricultural water resources by tailoring watering schedules to the specific needs of the plants, ensuring cost-effective and sustainable water use.
	W1T2	Farmers should adopt technologies and innovations to replace manual labor (e.g., automation and smart systems) across the entire planting process. This transition aligns with the principles of intelligent agriculture, enhancing efficiency and productivity while mitigating the labor shortage.
	W2T3	In response to the oversupply issue, a pivotal strategy involves the utilization of big data platforms to facilitate technological solutions that disseminate information across the pineapple supply chain. The primary objective is to improve the accuracy of market demand forecasting, enabling farmers to align their crop planning more efficiently with actual market conditions.

Conclusions

In this study, the analysis of flexibility performance in the pineapple supply chain clearly showed that pineapple farmers with GAP performed better than farmers without GAP. Additionally, the research identified the most important indicator, which is risk number 18 (uncertain changes in purchase price). This indicator hampers the flexibility of the supply chain's performance. Thus, pineapple farmers and relevant agencies must pay attention and find methods to eliminate the above indicator to increase efficiency in the supply chain. The result corresponds to analyzing the pineapple supply chain in Prachuap Khiri Khan, as mentioned. The market demand situation is the main issue in managing the supply chain and directly affects the purchase price.

Furthermore, the result of the risk assessment of pineapple farmers implemented both with and without GAP unidirectionally showed the risk score for five major risks, including risk numbers 2 (errors in forecasting and planting planning), 7 (lack of support for the production process development), 9 (severe drought or inadequate agricultural water supply), 16 (shortage of labor in the production process), and 18 (uncertain changes in purchase price). Additionally, the result of the risk assessment revealed two interesting observations. Pineapple farmers implemented with GAP effectively mitigated internal risks, including risk numbers 2, 9, and 16. Moreover, pineapple farmers who implemented GAP demonstrated increased awareness of external risks. This is evident in the risk assessment for risk numbers 7 and 18, which yielded higher risk scores compared to pineapple farmers without GAP.

As mentioned above, five significant risks within Thailand's pineapple supply chain were identified, consisting of forecasting errors, development shortages, water scarcity, labor shortages, and price uncertainties. These risks were used to create eleven strategies as follows: efficient loading and unloading equipment, queue management technology, technology and innovation, dealing with uncertain purchase prices, addressing water scarcity, handling labor shortages, establishing knowledge sharing centers, diversified distribution channels, coping with water shortages, replacing labor with technology, and utilizing big data for market demand forecasting. These strategies collectively will contribute to a more sustainable, efficient, and resilient Thailand's pineapple supply chain.

In addition to the study outputs, which encompass risk mitigation strategies and performance indicators for flexibility in the Thailand pineapple supply chain, the result of risk assessment from pineapple farmers with and without GAP can further extend the study towards an analysis of data sensitivity. Further studies, which focus on analyzing the perception of risks, found that pineapple farmers who implemented GAP had a higher probability or frequency of facing risks compared to farmers without GAP. This is an interesting issue that could lead to more specific risk mitigation strategies for pineapple farmers with GAP. Specifically, these strategies will motivate a shift towards cultivation, according to GAP.

References

[1] https://oae.go.th/assets/portals/1/fileups/prcaidata/files/Pineapple%2063(1).pdf (Accessed on 5 November 2023).

[2] https://oae.go.th/assets/portals/1/fileups/prcaidata/files/pinepple%2064.pdf (Accessed on 5 November 2023).

[3] https://impexpth.oae.go.th (Accessed on 5 November 2023).

[4] https://www.oae.go.th/ (Accessed on 5 November 2023).

[5] Mohamad, A.H.H., Ab-Rahim, R. and Mohamad, N.N. 2022. Competitiveness of Pineapple: Focus on the Southeast Asian Region. International Journal of Academic Research in Business and Social Sciences. 12(5): 205-214.

[6] https://www.oae.go.th/assets/portals/1/fileups/bappdata/files/Infographic_Q2_2566.pdf (Accessed on 5 November 2023).

[7] https://www.opsmoac.go.th/ratchaburi-dwl-files-431591791177 (Accessed on 5 November 2023).

[8] Phetchaburi College of Agriculture and Technology. 2018. Kon-Mai-Bpen-Sap-Bpa-Rot. Thailand.

[9] Phuangsubsin, C. and Liangrokapart, J. Risk Factors Study and Identification in Pineapple Supply Chain thought a Risk Assessment in the Cultivation Until Distribution Processes of Farmers. At 8th National Conference on Business Management and Innovation 2021 at Khon Kaen University, Thailand on September 25, 2021.

[10] Sinsuwanrak, S., Premanoch, P., Manakasettharn S. and Adulyaritthikul, P. 2023. Environmental Microbial Monitoring and Risk Assessment of Cleanrooms - A Case Study in Medical Device Pilot Plant. Thai Environmental Engineering Journal. 37(1): 1-12.

[11] Phuangsubsin, C. 2021. Risk Identification in Pineapple Supply Chain. Mahidol University Master's Thesis.

[12] Sooksaksu, N., Wavnum, K., Thepklang, J. and Seehaworg, S. 2023. The Application of Supply Chain Operations Reference (SCOR) Model: Herb Supply Chain in Dong Bang Village, Thailand. Engineering and Applied Science Research. 50(3): 244-250.

[13] Ayyildiz, E. and Gumus, A.T. 2021. Interval-Valued Pythagorean Fuzzy AHP Method-Based Supply Chain Performance Evaluation by a New Extension of SCOR Model: SCOR 4.0. Complex & Intelligent Systems.7: 559-576.

[14] Ramos, E., Coles, P.S., Chavez, M. and Hazen, B. 2022. Measuring Agri-Food Supply Chain Performance: Insights from the Peruvian Kiwicha Industry. An International Journal. 29(5): 1484-1512.

[15] Namugenyi, C., Nimmagadda, S.L. and Reiners, T. 2019. Design of a SWOT Analysis Model and its Evaluation in Diverse Digital Business Ecosystem Contexts. Procedia Computer Science. 159: 1145-1154.

[16] Weihrich, H. 1982. The TOWS Matrix—A Tool for Situational Analysis. Long Range Planning. 15(2): 54-66.

[17] https://www.opsmoac.go.th/prachuapkhirikhan-strategic-files-452791791795 (Accessed on 5 November 2023).

[18] Netsangsee, R. 2022. A Model for Developing Competence and Supply Chain Collaboration to Build Competitiveness of Pineapple Farmers in Loei Province. Journal of Logistics and Supply Chain College. 8(2): 112-125.