A STUDY ON THE RESILIENCY OF COFFEE ROASTER BUSINESS IN NORTHERN THAILAND REGION

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MASTER OF BUSINESS ADMINISTRATION

IN

INTERNATIONAL LOGISTICS AND SUPPLY CHAIN MANAGEMENT

SCHOOL OF MANAGEMENT

MAE FAH LUANG UNIVERSITY

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ABSTRACT

This study aims to identify and prioritize the factors that influence the resilience of coffee roasters in northern Thailand. Coffee is a primary agricultural product in Thailand, and the northern region is a crucial producer of Arabica coffee beans. Coffee roasters play an essential role in the coffee value chain, but their businesses are vulnerable to various risks. Coffee roasting businesses in northern Thailand face an increasingly complex and uncertain environment. This thesis examines the factors that influence the resilience of coffee roasters in the north of Thailand. The research uses a fuzzy analytical hierarchy process (fuzzy AHP) to identify and prioritize these factors. Fuzzy AHP is a multi-criteria decision-making tool that can prioritize factors in complex situations. It will analyze data from interviews with coffee roasters and industry experts. From the result of Fuzzy AHP The Fuzzy AHP analysis of coffee roasteries identified Turbulence (0.305) as the most significant. Deliberate threat (0.040) was ranked lowest in vulnerability factors. In terms of response capacity, flexible sourcing (0.233) emerged as the top priority and Anticipation (0.070) was the least prioritized respond capacity factor. The findings will be used to develop recommendations for improving the resilience of coffee roasters in northern Thailand.

Keywords: Coffee Roasting, Supply Chain Resilience, Fuzzy AHP, Northern Thailand

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CHAPTER 1

INTRODUCTION

1.1 Background

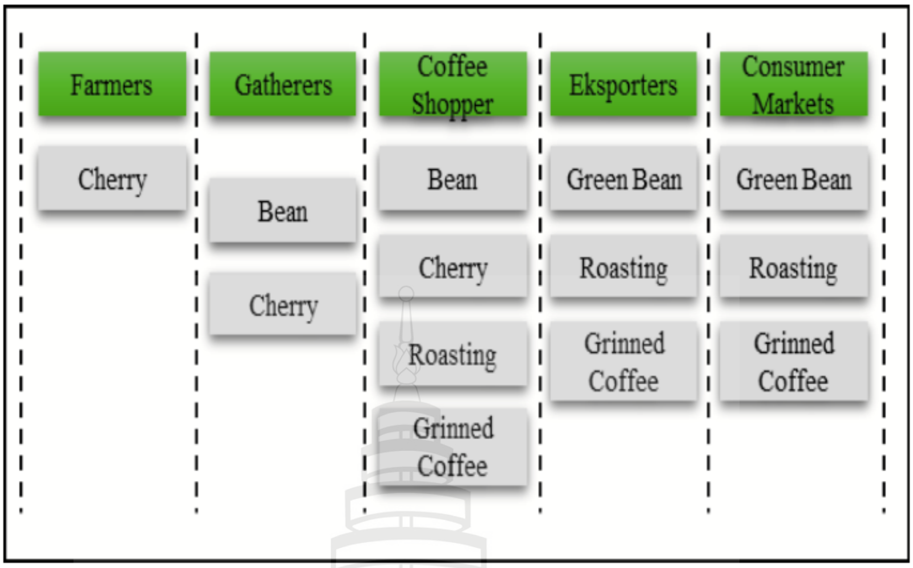
Coffee is a beverage made from green beans from a coffee tree. Coffee is the most popular beverage, and green bean coffee is one of the most important agricultural commodities worldwide. The coffee contains caffeine 80-140 milligrams, caffeine may keep you awake and fresh after drinking. Moreover, coffee is also the most essential tropical export crop in the world. 2 types of coffee are the most popular which are Arabica and Robusta. South America, the largest regional producer of Arabica coffee, increased its output 2.6% to 57.4 million bags. It is also the main region responsible for the 2.0% growth of Arabica coffee. In Asia and Oceania, Vietnam is the second largest coffee producer in Asia and Oceania, it produces 29.2 million bags in 2022-2023 (International coffee organization, 2023)

According to Thailand in 2017-2020, instant coffee is the most exported product in the coffee sector, exporting instant coffee on an average of 26,604.4 tons per year, and the main markets are Lao, Myanmar, Cambodia, Australia, Philippines (Bureau of Commodity Trade Department of International Trade Negotiations, 2021)

The global coffee and tea market is expected to grow from $100.82 in 2021 to $165.93 in 2026 at a CAGR of 10.48%. Rising health awareness and demand for ready-to-drink beverages are expected to drive the coffee and tea market. Nowadays, the population is more concerned about health and tends to change their lifestyle, so it expects to increase awareness of lifestyle disorders and awareness about diet and fitness will increase the consumption of coffee and tea as well as ready-to-drink beverages, ready-to-drink a single-use beverage and ready for consumption immediately. Ready-to-drink is popular among working adults. Introducing new flavors, ease of carrying, and convenience of ready-to-drink drinks are expected to boost the demand in the following market. (The Business Research Company, 2022)

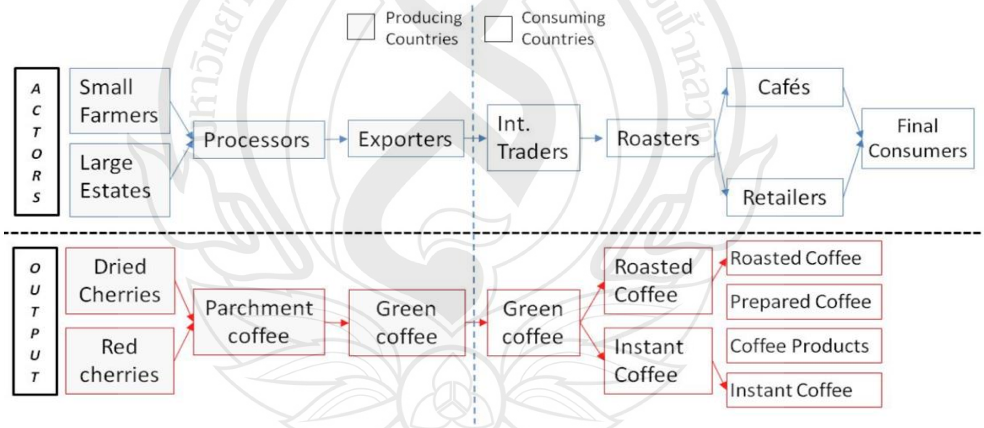
Another crucial sector in the coffee supply chain is the roasting sector or roastery, coffee must be processed into roasted coffee or instant coffee before consumption. After harvesting cherries and processing green beans, they will be sent to the coffee roastery to be processed into roasted coffee for sale in the domestic market or exported to another country. In Thailand, the processing of products still needs more development to meet standards, and there needs to be more quality processing machinery. According to Ebisa, (2017) Climate change affects coffee yield and quality and increases production costs, and if production costs are high, the selling price will be commonly the same. Roasters are affected when coffee producers are dealing with an unproductive season. Poor growing conditions will impact supplier performance, and the price of green coffee will usually rise. Bashiri et al. (2021) assume that climate change affected agricultural performance, which led to reduced exported coffee, which is the output.

According to Ikhwana (2018) The "supply chain of coffee consists of suppliers and distributors who play important roles in marketing processed coffee products." Moreover, they show the business activity from upstream to downstream in various elements in Figure 1.1 for the big picture and according to Tröster, (2015) show the global coffee commodity chain in figure 1.2 this framework is described in case of importing input or coffee bean from aboard to show the flow of actors in producing countries such as smallholder or commercial farmer and in part of output start from cherries until roasted or instant coffee.



Source Ikhwana (2018)

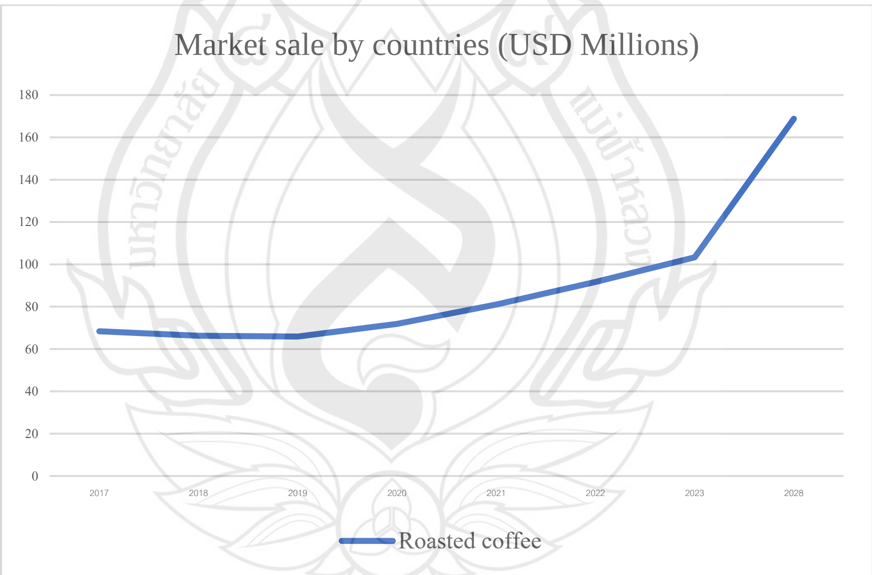
Figure 1.1 Business activity of processed coffee products



Source Tröster (2015)

Figure 1.2 Global coffee commodity chain

Figures 1.3 and 1.4 Focus on roasted coffee regarding market sales by countries and regions. The coffee market trend within the country is increasing continuously. Market sales by countries in 2021 are 81 million dollars, and in 2022, are forecasted to be 91.7 million dollars. In 2028, sales are forecast to be 168.78 million dollars. The CAGR is projected to change by 12.7% from 2023 to 2028 Perry/Hope Partners, (2022) Market sales by regions in 2021: The higher volume of sales is in northeastern (Isan) at 21,511 dollars and Bangkok Metropolitan at 20,057 dollars, followed by northern region sales at 13,434.9 dollars and southern 11,110.6 dollars. Within the country, the Thai coffee industry tends to grow positively according to the region's market sales volume. The sales increase yearly, and so do the market sales by country. This will benefit the coffee industry by developing and improving its potential to compete with its competitors and satisfy demand within the country or drive the economy in the agricultural sector.



Source Perry Hope Partners International Research (2022)

Figure 1.3 Market sale and forecast of roasted coffee by countries

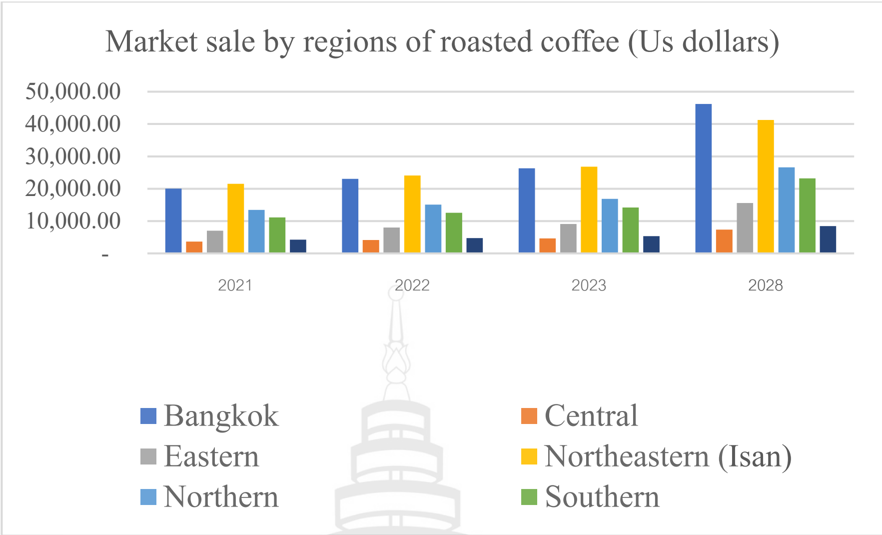


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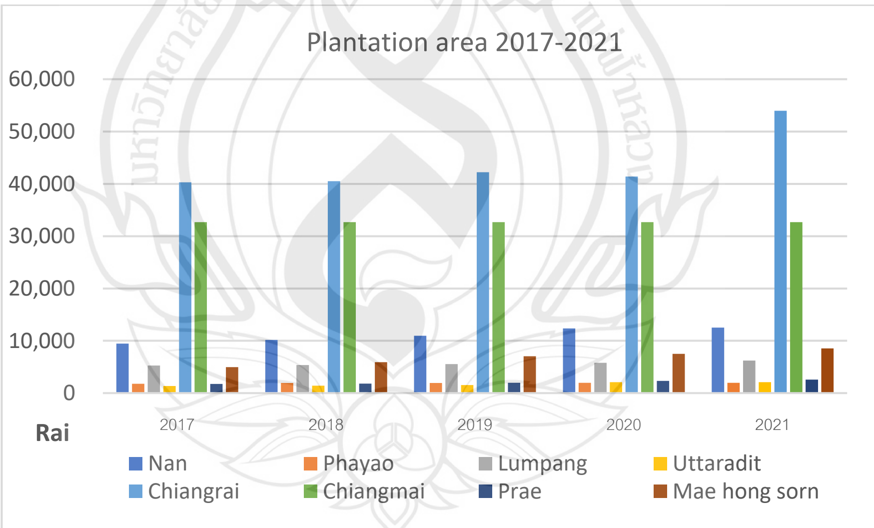
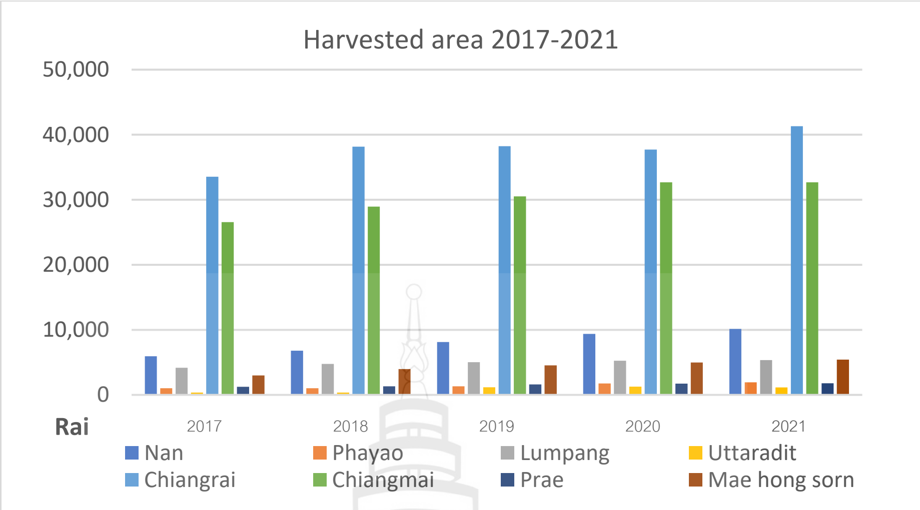
Figure 1.4 Market sale and forecast of roasted coffee by regions of Thailand



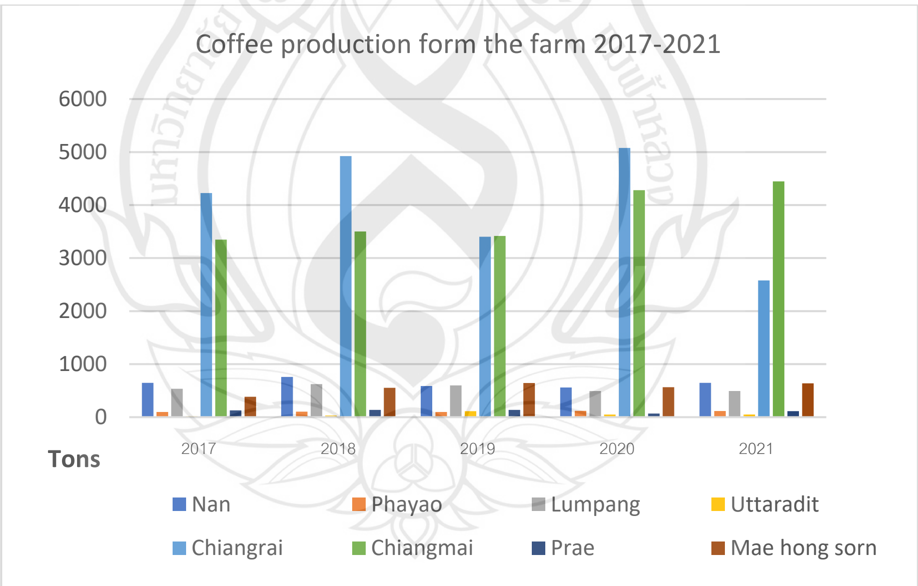
Source Office of Agricultural Economic (n.d.)

Figure 1.5 Coffee plantation area in northern region 2017-2021



Source Office of Agricultural Economic (n.d.)

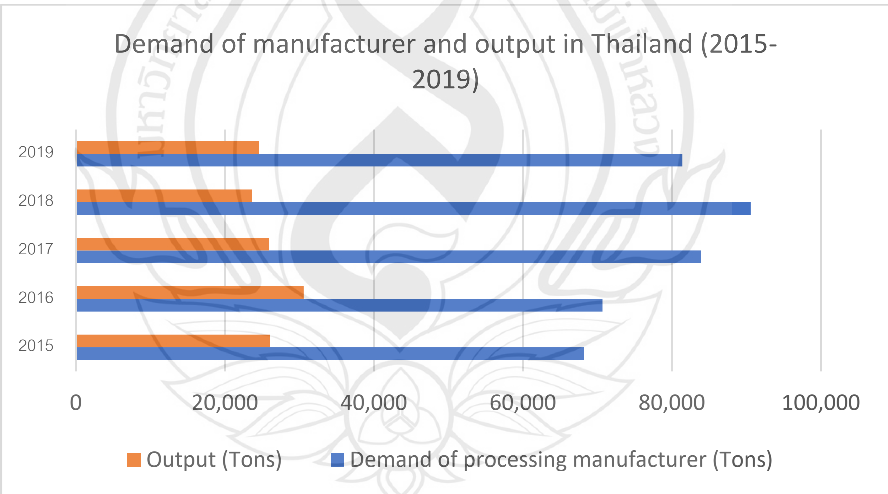
Figure 1.6 Coffee harvested area in northern region 2017-2021



Source Office of Agricultural Economic (n.d.)

Figure 1.7 Coffee production in northern region 2017-2021

The plantation area harvested area and the output of green coffee beans are in figures 1.5, 1.6, and 1.7. In 2017, they had 97,536 Rai for the plantation area, 75,834 for the harvest area, and 9,385 Tons for output, but in 2021, the plantation area increased to 120,576 Rai, 99,759 for the harvest area, and they got 9,081 tons for output. The plantation and harvest area have been increasing continuously as a result of the development of the coffee industry, except for the output, which did not increase as expected due to the climate change poses significant risks to the coffee industry, including temperature variability, altered rainfall patterns, increased pests and diseases, extreme weather events, and water scarcity. These factors can reduce yields, damage crops, and degrade soil quality. Arabica is mainly planted in northern Thailand, such as in Chiangmai and Chiang Rai provinces, as shown in the above picture. Coffee plantation data in Thailand are associated with the regions of northern Thailand that mostly produce Arabica coffee. Provinces that have the most potential to produce coffee are Chiangmai (47%), Chiang Rai (27%), Mae Hong Son (7%), and Nan (7%). Office of Agricultural Economics (2022)



Source Ministry of agriculture and cooperative, Office of agricultural economics consolidate by researcher

Figure 1.8 Output of coffee green bean and demand of manufacturer in Thailand (2015-2019)

Figure 1.8 represents Thailand's manufacturer's output and demand from 2015 to 2019. The average demand is 78,954 tons annually, but they can produce 26,612 tons annually. As a result, the production is insufficient to meet the consumer demand in the country, so they must import the product to fulfill the demand. Thus, it is an opportunity for the Thai coffee industry to increase and develop productivity or create new products to meet the needs of domestic and international consumer demand.

1.2 Research Objective

1.2.1 To identify the risk factors that influencing to coffee roaster in northern region of Thailand.

1.2.2 To validate risk factor facing by coffee roasters in northern region.

1.2.3 To prioritize factors that influence coffee roasteries.

1.2.4 To propose recommendation and suggestion to control vulnerability of coffee roaster.

1.3 Scope of Study

The study aims to prioritize the significant factors using the fuzzy analytic hierarchy process (Fuzzy AHP) method based on the supply chain resilience concept. Small-scale coffee roasters are the population of this research. Experts from each coffee roastery will identify the sample size. The risk factor will be gained after interviewing with all experts and will be prioritized using Fuzzy AHP to evaluate the data collected from the survey. The result of this study can provide recommendations or suggestions for other individuals, local or governments that act or manage the roastery section in the coffee industry or related field for improvement and adaption and will help researchers to understand the resilience concepts by prioritizing factors that influenced the coffee roastery and any related field under the supply chain resilience concept to prepare and resist possible disruption and unpredicted events.

1.4 Conceptual Framework

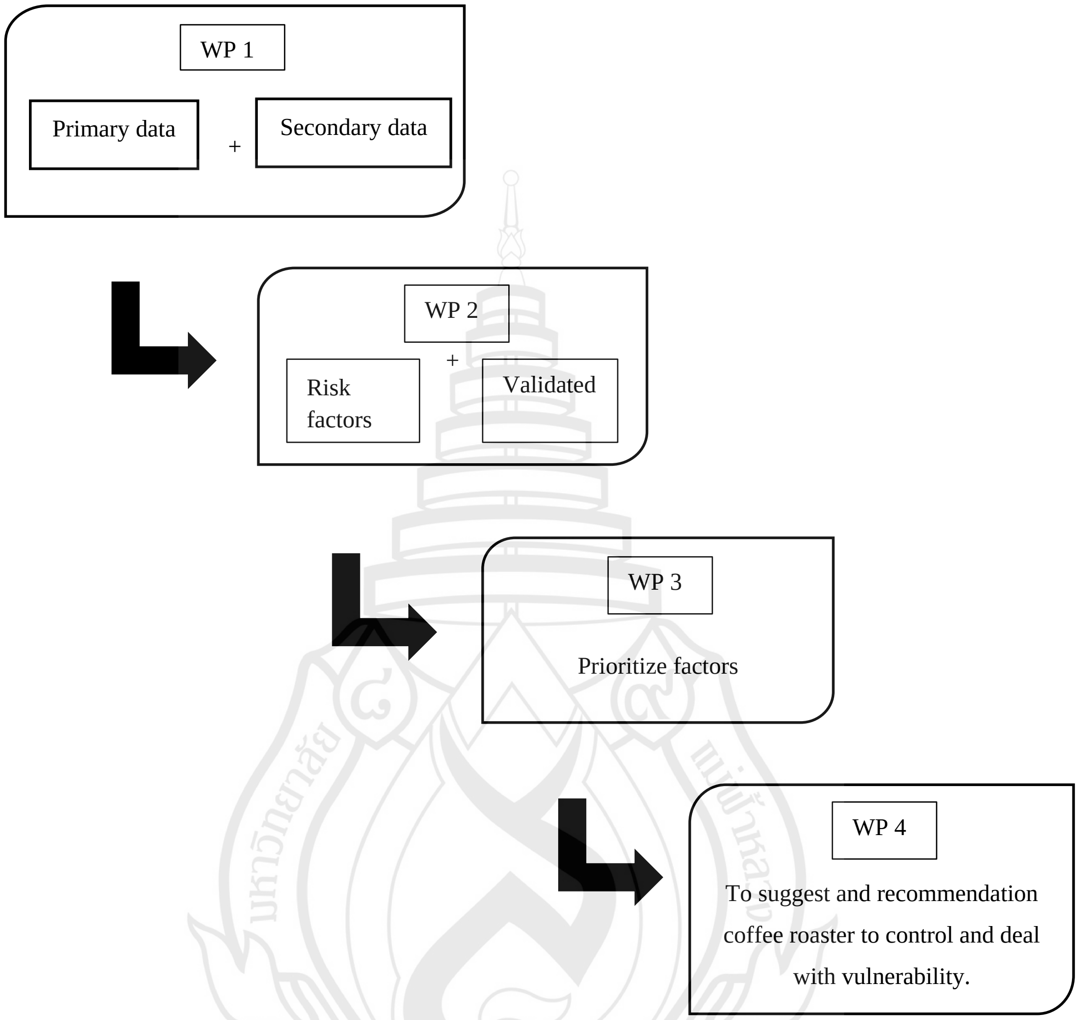


Figure 1.9 Conceptual Framework

This illustration illustrates the conceptual framework of this research. The factors influencing coffee roasters in the northern region were selected based on results from interviews with the experts and a literature review. The experts from each coffee roastery will validate risk factors with significance; the data will be used to evaluate and prioritize factors that influence the coffee roaster. After the analysis, this study aims to provide recommendations and suggestions for improving and developing coffee roasteries in the northern region.

1.5 Summary Table

Table 1.1 Summary table

Research objective	Method	Expect outcome
Investigate and identify risk factors	Semi structure interview	Risk factors influencing coffee roasters in northern region
Validate risk factor	Fuzzy AHP	Validated risk factors
To propose recommendation and suggestion	Qualitative analysis	Recommendation and suggestion for coffee roasters

CHAPTER 2

LITERATURE REVIEW

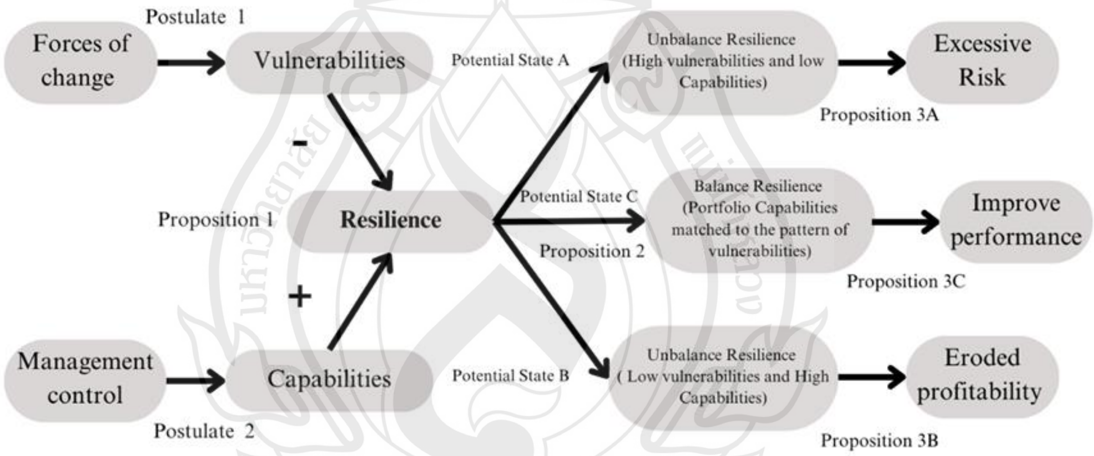
2.1 Supply Chain Resilience and Application of Resilience Concept

According to Ponis and Koronis (2012) state that supply chain resilience is the ability of a supply chain system to reduce the emergence of mistake, error, or disruption in supply chain and organization and to reduce the outcome of those disruptions when occur and to reduce the time to recovery existing performance. According to Ivanov (2021) supply chain resilience theory is about how one can maintain when facing disruptions. Supply chains play an important economic role by providing goods and services in many industries, such as food, logistics, transportation, and mobility. In the supply chain, resilience ensures operations are likely to avoid face disruption. Disruption and crisis are linked to the resilience of the supply chain. If supply chains are not flowing or resilient or are not concerned about the resilience of supply chains when facing disruptions, then we will be at risk of shortages of products or services. Hohenstein et al. (2015) concluded that supply chain resilience is the ability to prepare and recovering for unforeseen event, risk, or disruption that effect to the supply chain performance to increase customer satisfaction, market share and about the financial performance. Ponomarov and Holcomb (2009) It states that supply chain resilience is the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover by maintaining and developing the operation. In terms of the supply chain, disruption can occur from external and internal sources, and disruption is affected either upstream or downstream of the supply chain.

Moreover, resilience concept has been applied in many fields with different reason for example, Elleuch et al. (2016) resilience is used in many fields, such as engineering, environment science, agriculture, and organization research. In the engineering industry, supply chain resilience becomes an important factor for managers.

Supply chains are increasing in the global economy, and resilience can get the company a competitive advantage in market. Xu et al. (2021) using the resilience concept is to be studied to enhance the resilience of water resource management in the agricultural supply chain. To reduce the risk and deal with water shortage, researchers must improve the resilience of the agricultural supply chain. Researchers use the concept of resilience to deal with risk and to identify the factors affecting water management in the agricultural supply chain for a sustainable agricultural supply chain. Machado-Vargas et al. (2018) adapt the resilience concept for assessment risk in terms of social-ecological to propose the level of resilience for each population in the specific areas to assess the risk, which coffee producers' farms contain a high or low resilience level. The indicator to define social-ecological resilience was established through a systematic review. The social, economic, and environmental indicators are selected to show the vulnerability and response capacity of the study. Ni et al. (2022) proposes a systematic method for evaluating the resilience of the supply chain, specifically applied to the demand side management of a downstream oil supply chain and introduces two indices for making a quantitative resilience assessment of the studied downstream oil supply chain to propose an inventory strategy that is applied to different scenarios, and shows that increasing the inventory of storage depots can improve the resilience of the supply chain. (Yang et al., 2023) emphasizes the need for more effective supply chain resilience strategies for firms, industries, nations, and the world and highlights the importance of fundamental research in this area. The authors also propose a framework for measuring supply chain resilience, including three major capacities: absorptive, adaptive, and restorative capacity. These capacities represent preparing for emergencies, responding to emergencies, and recovering from emergencies. Rajesh (2021) provides insights to managers for making decisions related to flexibility implementation to enhance resilience in supply chains and identifies five major flexible business strategies for building resilience in supply chains which are flexible supply strategy via multiple suppliers, flexible supply contracts, flexible manufacturing process, flexible product strategy via postponement, flexible pricing strategy via responsive pricing.

According to Pettit et al. (2010) the study emphasized the importance of balancing capabilities and vulnerabilities to create a competitive advantage in supply chain management. It developed the supply chain resilience framework that guides priorities for improving Supply Chain Resilience based on vulnerabilities, competitive advantages, and return on investment. Periodic supply chain resilience assessment is necessary for well-managed enterprises to realign resources faster than rivals. The research consolidates literature on supply chain disruptions, translating resilience concepts into a practical framework for decision-making. Three potential states of resilience are shown in Figure 2.1 below. Implementing the vulnerability and capability to show and recognize the need to balance supply chain capabilities and vulnerability is asserted by three propositions. They stated that "excessive vulnerabilities relative to capabilities will result in excessive risk, supply chain performance improves when capabilities and vulnerabilities are more balanced, and excessive capabilities relative to vulnerabilities will decrease profitability. Resilience is not just about strengths but also the balance between capabilities and vulnerabilities.



Source Pettit et al. (2010)

Figure 2.1 Supply chain resilience framework

Moreover, in this paper identified capabilities factors with definition and sub factor for each factor to provide the knowledge of indicators are shows in table 2.1 which are encouraged to increasing supply chain resilience performance and consolidate the wide range of literature on supply chain disruption to identify supply chain vulnerabilities show in table 2.2 below. Vulnerabilities and response capacity factors were identified through focus group discussions at limited brands. During eight focus groups comprising two to four members with similar backgrounds, members shared their experiences with recent supply chain disruptions. The refined supply chain resilience taxonomy was presented during these discussions. Members were encouraged to match their experiences with this framework, resulting in the identification of 50 vulnerability examples and 96 specific capabilities related to supply chain resilience. An open discussion format allowed members to share their experiences and insights freely. This approach helped identify gaps and redundancies in the supply chain resilience taxonomy without biasing the group members' opinions. The process of discussing vulnerabilities and response capacity factors during these focus groups was effective in capturing real-world experiences and practical insights. This direct engagement with industry professionals contributed significantly to developing the supply chain resilience framework, as presented in the research paper. The insights gathered from the focus groups provided a rich source of information for understanding the specific vulnerabilities faced by supply chains in practice. These first-hand accounts helped create a comprehensive and practical framework that can guide managers in strengthening their supply chain resilience capabilities.

Table 2.1 Respond capacity factors definition and sub-factors

Respond Capacity Factors	Definition	Sub-Factors
Flexible in sourcing	Ability to quickly change inputs or the mode of receiving inputs	Part commonality, Modular product design, Multiple uses, Supplier contract flexibility, Multiple sources
Flexibility in order fulfillments	Ability to quickly change outputs or the mode of delivering outputs	Alternate distribution channels, Risk pooling/sharing, Multi-sourcing, Delayed commitment, Production postponement, Inventory management, Re-routing of requirements

Table 2.1 (continued)

Respond Capacity Factors	Definition	Sub-Factors
Capacity	Availability of assets to enable sustained production levels	Reserve capacity, Redundancy, Backup energy sources and communications
Efficiency	Capability to produce outputs with minimum resource requirements	Waste elimination, Labor productivity, Asset utilization, Product variability reduction, Failure prevention
Visibility	Knowledge of the status of operating assets and the environment	Business intelligence gathering, Information technology, Products, Assets and People visibility, Information exchange
Adaptability	Ability to modify operations in response to challenges or opportunities	Fast re-routing of requirements, Lead time reduction, Strategic gaming, and simulation, seizing advantage from disruptions, Alternative technology development, Learning from experience
Anticipation	Ability to discern potential future events or situations	Monitoring early warning signals, Forecasting, Deviation and Near-miss analysis, Contingency planning, Preparedness, Risk management, Business continuity planning, Recognition of opportunities
Recovery	Ability to return to normal operational state rapidly	Crisis management, Resource mobilization, Communications strategy, Consequence mitigation

Table 2.1 (continued)

Respond Capacity Factors	Definition	Sub-Factors
Dispersion	Broad distribution or decentralization of assets	Distributed decision-making, Distributed capacity and assets, Decentralization of key resources, Location-specific empowerment, Dispersion of markets
Collaboration	Ability to work effectively with other entities for mutual benefit	Collaborative forecasting, Customer management, Communications, Postponement of orders, Product life cycle management, Risk sharing with partners
Market position	Status of a company or its products in specific markets	Product differentiation, Customer loyalty/ retention, Market share, Brand equity, Customer relationships, Customer communications
Organization	Human resource structures, policies, skills and culture	Learning, Accountability and Empowerment, Teamwork, Creative problem solving, Cross-training, Substitute leadership, Culture of caring
Security	Defense against deliberate intrusion or attack	Layered defenses, Access restrictions, Employee involvement, Collaboration with governments, Cyber-security, Personnel security
Financial strength	Capacity to absorb fluctuations in cash flow	Insurance, Portfolio Diversification, Financial reserves and liquidity, Price margin

Source Pettit et al. (2010)

Table 2.2 Vulnerability factors definition and sub-factors

Vulnerability Factors	Definition	Sub-Factors
Turbulence	Environment characterized by frequent changes in external factors beyond your control	Natural disasters, Geopolitical disruptions, Unpredictability of demand, Fluctuations in currencies and prices, Technology failures, Pandemic
Deliberate Threat	Intentional attacks aimed at disrupting operations or causing human or financial harm	Theft, Terrorism/sabotage, Labor disputes, Espionage, Special interest groups, Product liability
External Pressure	Influences, not specifically targeting the firm, that create business constraints or barriers	Competitive innovation, Social/ Cultural change, Political/ Regulatory change, Price pressures, corporate responsibility, Environmental change
Resource Limits	Constraints on output based on availability of the factors of production	Supplier, Production and Distribution capacity, Raw material and Utilities availability, Human resources
Sensitivity	Importance of carefully controlled conditions for product and process integrity	Complexity, Product purity, Restricted materials, Fragility, Reliability of equipment, Safety hazards, Visibility to stakeholders, Symbolic profile of brand, Concentration of capacity

Table 2.2 (continued)

Vulnerability Factors	Definition	Sub-Factors
Connectivity	Degree of interdependence and reliance on outside entities	Scale of network, Reliance upon information, Degree of outsourcing, Import and Export channels, Reliance upon specialty sources
Supplier and Customer disruption	Susceptibility of suppliers and customers to external forces or disruptions	Supplier reliability, Customer disruptions

Source Pettit et al. (2010)

2.2 Fuzzy Analytic Hierarchy Process (FAHP) Multi Criteria Decision Making and Application

The Fuzzy Analytic Hierarchy Process (FAHP) are proposed by van Laarhoven and Pedrycz (1983) for solving complex decision-making problem and Radivojević and Gajović (2014) state that method extends the AHP method by combining it with the fuzzy set theory and describe AHP method cannot be able to present human cognitive processes. Liu et al. (2020) state that Fuzzy Analytic Hierarchy Process (FAHP) is widely used for solving and making decision purpose and also using to identify the weight of criteria and priorities of alternatives in a structure manner and Güngör et al. (2009) state that Fuzzy AHP is a systematic approach to the alternative selection and justify problem by using concept of Fuzzy theory combine with hierarchical structure analysis also known as AHP. Chang (1996) represent the new approach to handling Fuzzy AHP by using triangle fuzzy number for pairwise comparison scale of Fuzzy AHP. Many researchers are applied Fuzzy AHP method in several studies with the different purpose and to solve different problem. According to Ganguly and Kumar (2019) assessing supply chain risk by used Fuzzy based Analytic Hierarchy Process and to identify the major risk factor in supply chain. Mangla et al. (2015) applied Fuzzy AHP method to analyze the identified risks for determining of their priority of concern to know the most significant risk factor in green supply chain and state that Fuzzy AHP is also useful in dealing with the human subjectivity and ambiguity. Shaw et al. (2012) used Fuzzy AHP method for analyze the weight of the multiple factors combine with fuzzy multi-objective linear programming to find out the optimum solution of the problem for developing low carbon supply chain. According to Samvedi et al. (2013) using Fuzzy AHP and Fuzzy TOPSIS to quantify supply chain risk, the fuzzy values are helping to capturing the subjectivity. Radivojević and Gajović (2014) ranking risk that according to supply chain by using Fuzzy AHP method proposed approach of this research are based on perspective from experts in specific company.

2.3 Triangular Fuzzy Numbers (TFN)

Triangle fuzzy numbers are widely used in fuzzy logic and fuzzy systems due to their simplicity and effectiveness in modeling uncertainty. Triangle fuzzy numbers are defined by three parameters (a, b, c), where 'a' and 'c' are the lower and upper bounds of the interval, and 'b' is the peak or central value. This simplicity makes them easy to understand and work with Klir and Yuan (1995). While triangle fuzzy numbers are simple, they can effectively model a wide range of uncertain or ambiguous information. Their triangular shape allows for a balance between precision and flexibility in representing fuzzy concepts (Zadeh, 1975). Triangle fuzzy numbers can be easily integrated with other types of fuzzy numbers or fuzzy sets, allowing for more complex and nuanced modeling of uncertainty in fuzzy systems Dubois and Prade (1988). TFNs provide a straightforward yet effective way to represent uncertainty and fuzziness in numerical values. Their triangular shape and three defining values make them a practical tool for assessing student skills and other complex scenarios where traditional crisp numbers fall short Voskoglou (2015)

These symbols are used in various equation of FAHP, Rabten et al. (2021)

μÃ (x)	=	Membership function of Ã fuzzy set
TFN	=	Triangular Fuzzy Numbers
1	=	Smallest probable value
m	=	Most probable number
u	=	Largest probable value
Si	=	Synthetic extents value
μd	=	Intersection between two fuzzy numbers
Ci	=	Weight of criteria
W’	=	Weight vector

μÃ (x) can be represent for the membership function of fuzzy set Ã Güngör et al. (2009). The membership of triangular fuzzy numbers Ã on R is derived as R→ [0, 1] denoted with (l, m, u) can be represented as the following equation (1) Rabten et al. (2021) so from the conclusion ‘m’ is most probable number and ‘u’ is largest probable value.

$$\mu\tilde{A}(x) = \begin{cases} \frac{(x-1)}{(m-1)}, & X \in [1, m], \\ \frac{(x-u)}{(m-u)}, & X \in [m, u], \\ 0 & \text{Otherwise} \end{cases} \tag{2.1}$$

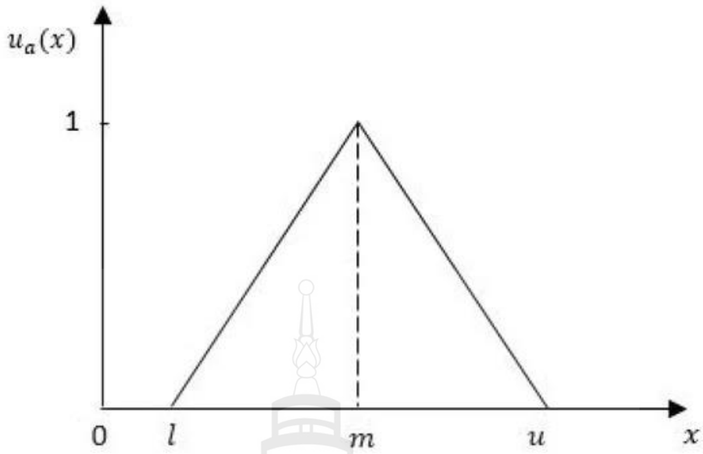


Figure 2.2 Triangular fuzzy numbers

Then there is various important operation on Triangular Fuzzy Numbers if (a1, b1, c1) and (b1, b2, c2) is Triangular Fuzzy Numbers are shown in the following equations 2-6 below (Patil, 2018)

Addition: (a1, b1, c1) + (a2, b2, c2) = (a1+a2, b1+ b2, c1+ c2) (2.2)

Subtraction: (a1, b1, c1) - (a2, b2, c2) = (a1-a2, b1- b2, c1- c2) (2.3)

Multiplication: (a1, b1, c1) X (a2, b2, c2) = (a1a2, b1 b2, c1 c2) (2.4)

Division: (a1, b1, c1) ÷ (a2, b2, c2) = (a1/a2, b1/b2, c1/ c2) (2.5)

Inverse: (a1, b1, c1) = (1/ c1, 1/ b1, 1/ a1) (2.6)

Method of extent analysis values for each decision maker can be obtain, with equation (2.7) below;

$M^1_{gi,}$, M^2_{gi}, M^3_{gi},…, M^m_{gi}, (I = 1, 2, 3, n),

Where all the $M^j_{gi,}$ (j = 1,2,3, m) are TFN (2.7)

If $M^1_{gi,}$, M^2_{gi}, M^3_{gi},…, M^m_{gi} is value of extent analysis of i^{th}

First step, the fuzzy synthetic extent values for i^{th} can be calculate by using equation below;

$$S_i = \sum^{m}{}_{j=1} M^j \text{ x } [\sum^{n}{}_{i=1} \sum^{m}{}_{j=1} M^j]$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} lij , \sum_{j=1}^{m} mij , \sum_{j=1}^{m} uij \right)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right] = \left(\frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} uij}, \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} mij}, \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} lij}\right)$$

Second step, the degree of possibility of criteria of M2 greater than equal M1 is define as below;

$$V (M_2 \geq M_1) = \max (M_2 \cap M_1) = \mu(d) = \begin{cases} = 1 \text{ if } m_2 \geq m_1 \\ = 0 \text{ if } m1_2 \geq u_2 \\ = \dfrac{l1\text{-}u2}{(m2\text{-}u2)\ (m1\text{-}l1)} \quad \text{otherwise} \end{cases} \qquad (2.8)$$

Then μd = intersection between two fuzzy numbers do assume that d' (A_i) = min $V(S_i \geq S_k)$ for k = 1, 2, … n ($k \neq i$). he weight vector is given by

$$W' = (d' (C_1), d' (C_2),..., d' (C_n))^T, \qquad (2.9)$$

And C_i (i = 1, 2, 3, 4, 5,…,n) are the weight of criteria.

Final step, the normalized weight vectors of each criterion can be defined as below;

$$W = (d (C_1), d (C_2), d (C_n))^T, \qquad (2.10)$$

Table 2.3 The scale of Fuzzy AHP pair-wise comparison

	Linguistic variables	L	M	U
9	Extreme importance	9	9	9
8	Very strong to extreme importance	7	8	9
7	Very strong importance	6	7	8
6	Strong to very strong importance	5	6	7
5	Strong importance	4	5	6
4	Moderate to strong importance	3	4	5
3	Moderate importance	2	3	4
2	Equal to moderate importance	1	2	3
1	Equally importance	1	1	1

Source Chang (1996)

CHAPTER 3

RESEARCH METHODOLOGY

This chapter includes four parts: research design, data collection, data analysis, and analysis framework. A Fuzzy AHP or Fuzzy Analytic Hierarchy Process will be used to find significant factors that influence coffee roastery and validate factors by experts from each coffee roastery prioritize the factors that influence coffee roastery in the northern region to provide recommendations and suggestions for preparing and resisting possible disruption and unpredicted events.

3.1 Research Design

This research uses quantitative and qualitative methods to explore and analyze the data. Factors influencing coffee roastery are collected by an in-depth semi-structured interview from the perspective of experts from each roastery under the vulnerability and response capacity dimension. The data were collected using a questionnaire to compile information. The data from the interview will be analyzed using Fuzzy AHP to prioritize significant factors influencing the coffee roastery and provide recommendations and suggestions for improving and developing the coffee roastery in the northern region.

3.2 Data Collection

3.2.1 In-depth Expert Interview

The questionnaire is semi-structured and designed by the researcher to understand the challenges and factors that influence roastery operations in the northern region. This in-depth interview aims to investigate and establish the factors influencing coffee roastery operations in the northern region under the supply chain resilience concept.

3.2.2 Population and Sample Size

Experts selected via purposive sampling who are directly involved with the small-scale coffee roasters in the northern provinces of Thailand, which have the most significant production potential. Also, experts directly involved with the coffee roastery, are identified as the sample size. The coffee roastery is still specific, and not many people are working there. Therefore, the population size of this research is experts or those related to the roasting section. The target group is based on the small scale of the business.

3.3 Data Analysis

Experts were asked to compare factors in each dimension on a Fuzzy AHP pairwise comparison scale. They are using a scale of Fuzzy AHP in Table 2.1 for the pairwise comparison scale of Fuzzy AHP. The data on pairwise comparison metrics are mean and obtained from expert opinion.

3.3.1 Fuzzy AHP Method

The significant factors influencing coffee roastery are established and collected from a literature review and in-depth interviews with experts who are working directly with coffee roastery around northern regions. The data will be analyzed using the Fuzzy AHP method. The step of the Fuzzy AHP method is shown below.

Step 1 Fuzzy synthetic extent's value with respect to i-th criterion shown as below:

$$S_i = \sum^{m}{}_{j=1} M^j \text{ x } [\sum^{n}{}_{i=1} \sum^{m}{}_{j=1} M^j]$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} lij , \sum_{j=1}^{m} mij , \sum_{j=1}^{m} uij \right)$$

$$\left[\sum_{i=1}^{n} \ \sum_{j=1}^{m} M_{gi}^{j} \ \right] = \left(\frac{1}{\sum_{n}^{i=1} \ \sum_{m}^{j=1} \ uij}, \frac{1}{\sum_{n}^{i=1} \ \sum_{m}^{j=1} \ mij}, \frac{1}{\sum_{n}^{i=1} \ \sum_{m}^{j=1} \ lij} \right) \qquad (3.1)$$

Step 2 The degree of possibility of criteria shown as below.

$$V (M_2 \geq M_1) = \max (M_2 \cap M_1) = \mu(\text{d})$$

$$= \begin{cases} = 1 \text{ if } m_2 \geq m_1 \\ = 0 \text{ if } m1_2 \geq u_2 \\ = \frac{l1-u2}{(m2-u2)\,(m1-l1)} \end{cases} \quad (3.2)$$

µd = intersection between two fuzzy numbers do assume that $d'(A_i)$ = min$V$ (Si ≥ Sk) for k = 1, 2,… n ($k \neq i$). The weight vector is given by

$$W' = (d'(C_1), d'(C_2),..., d'(C_n))^T, \quad (3.3)$$

And C_i (i = 1, 2, 3, 4, 5,…,n) are the weight of criteria.

Step 3 The normalized weight vectors of each criterion can be defined as below;

$$W = (d (C_1), d (C_2), d (C_n))^T, \quad (3.4)$$

3.3.2 Consistency Ratio

According to Saaty (1990) provides a detailed explanation of the AHP and process of calculating the CR is shown below.

Step 1 Construct Pairwise Comparison Matrix

Construct the pairwise comparison matrix (A) where each element $a\ i\ j$ represents the relative importance of criterion i compared to criterion j.

Step 2 Calculate the Weighted Sum Vector

Multiply the pairwise comparison matrix (A) by the eigenvector (W), which is the vector of relative weights of the criteria by using equation below.

$$AW = \lambda_{\max} W \quad (3.5)$$

Step 3 Compute the Principal Eigenvalue (λ max) by using equation below.

$$\lambda_{\max} = \frac{(AW)_i}{W_i} \quad \forall i \tag{3.6}$$

Step 4 Calculate the Consistency Index (CI) where n is the number of criteria by using equation below.

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{3.7}$$

To obtain the Random Consistency Index (RI), The Random Consistency Index (RI) is a constant derived from a sample of randomly generated pairwise comparison matrices Yap et al. (2018) It depends on the size of the matrix by following table below.

Table 3.1 The Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 5 Calculate the consistency ratio (CR) by using equation below.

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{3.8}$$

3.4 Analysis Framework

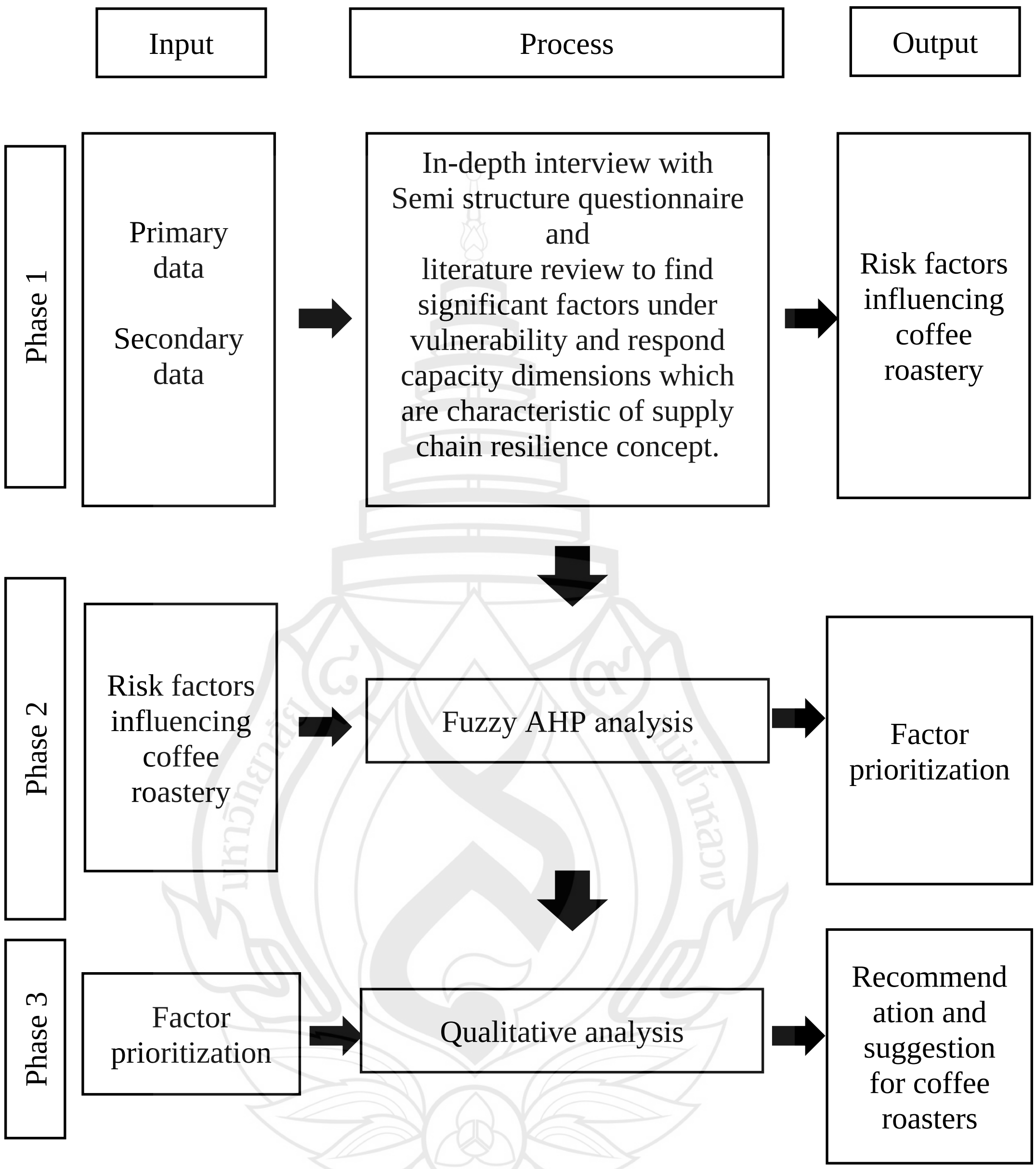


Figure 3.1 Analysis framework

According to figure 3.1 show the analysis framework of this research. Phase 1 the primary data in this research are the data from in-depth interview with semi structure questionnaire then secondary data was in the form of literature review which is the concept of supply chain resilience of Pettit et al. (2010). Factor influencing coffee roastery will be analyze by content analysis and using Fuzzy AHP to prioritize the significant factor in phase 2. After that in phase 3 will be using qualitative analysis for evaluate the content to propose suggestion and recommendation for coffee roasteries.

CHAPTER 4

FINDING

This chapter discusses the significant factors that influence the roastery in the northern region, which involve the supply chain resilience concept. Detailed information on respondents is provided, and the results are obtained from Fuzzy AHP analysis. The factors influencing coffee roasters under dimensions are vulnerability and response capacity. They are collected and established based on a literature review and in-depth interviews with the experts from each coffee roastery to find and interpret the factors that are valuable and influencing the coffee roastery in the northern region. Respondents are experts working in the north region area, which has the highest productivity in producing coffee.

4.1 Thesis Respondents

The thesis respondents are individuals who have been directly involved in the coffee roasting business for more than five years. Each of these respondents are the owner of their respective coffee roasting business. Additionally, based on survey the respondents are predominantly males in the age group of 21-35 with 5 years of experience. There is also a single female respondent in the same age group of 21-35 with 5 years of experience and there is one respondent in the age group of 36-50. There are business owners operate in the northern provinces of Thailand, specifically in Chiang Rai and Chiang Mai. These details ensure that the respondents have having a significant amount of experience in a particular field, the individuals have been involved in their positions for a considerable period in the industry and provide insights specific and make decision based on those perspective and bias to the coffee roasting businesses in that geographical area.

Table 4.1 Vulnerability factor influencing the coffee roastery business in northern Thailand region

Criterion	Sub-criteria
Vulnerability	1. Turbulence 2. Deliberate threat 3. External pressure 4. Resource limits 5. Sensitivity 6. Connectivity 7. Supplier and customer disruption

Table 4.2 Respond capacity factor influencing the coffee roastery business in northern Thailand region

Criterion	Sub-criteria
Respond capacity	1. Flexible in sourcing 2. Flexible in order fulfillments 3. Capacity 4. Efficiency 5. Visibility 6. Adaptability 7. Anticipation

In the context of a coffee roastery, it is crucial to focus on specific vulnerabilities and response capacity factors that directly impact operations. Key vulnerabilities include Turbulence Deliberate threat, and External pressure, which affect the stability and resilience of the coffee market. Resource limits and Sensitivity are also critical as they influence coffee bean production and quality. Connectivity and Supplier and customer disruption are vital for maintaining consistent operations. For response capacity, despite initially considering financial strength and organization, we found these factors to be not influential for the coffee roastery. Instead, the response capacity is more significantly impacted by concentrating on these specific factors. After engaging in discussions and interviews with industry experts, through a careful evaluation process, the experts identified and prioritized the 7 most critical factors, based on their experience on the business. these 7 factors were chosen because they are the most influential in driving strategic decisions in the coffee roasting industry. This focused approach helps the roastery navigate challenges effectively, maintain high-quality output, and ensure customer satisfaction, ultimately contributing to its resilience and success. Additionally, having access to timely and accurate information about market position is crucial for strategic planning and risk management, by concentrating on these specific factors. Coffee roastery can better understand its unique vulnerabilities and enhance its capacity to respond effectively to potential disruptions. This focused approach ensures sustained operations and quality output amidst various challenges.

4.2 Fuzzy AHP Results

Table 4.3 Pairwise comparison matric respect to vulnerability

	Turbulence	Deliberate threat	External pressure	Resource limits	Sensitivity	Connectivity	Supplier and customer disruption
Turbulence	(1.000, 1.000, 1.000)	(1.000, 1.800, 2.500)	(3.000, 5.000, 7.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(2.000, 3.000, 4.000)	(2.000, 2.500, 3.000)
Deliberate threat	(0.400, 0.556, 1.000)	(1.000, 1.000, 1.000)	(0.600, 0.800, 1.000)	(0.750, 1.000, 1.250)	(1.000, 1.200, 1.500)	(2.000, 3.000, 4.000)	(2.500, 3.500, 4.500)
External pressure	(0.143, 0.200, 0.333)	(1.000, 1.250, 1.667)	(1.000, 1.000, 1.000)	(0.900, 1.100, 1.300)	(0.500, 0.667, 0.833)	(1.500, 1.800, 2.000)	(1.500, 2.000, 2.500)
Resource limits	(0.250, 0.333, 0.500)	(0.800, 1.000, 1.333)	(0.769, 1.100, 1.429)	(1.000, 1.000, 1.000)	(1.000, 1.500, 2.000)	(0.833, 1.200, 1.667)	(1.500, 2.500, 3.500)
Sensitivity	(0.250, 0.333, 0.500)	(0.667, 0.833, 1.000)	(1.200, 1.500, 1.800)	(0.500, 0.667, 1.000)	(1.000, 1.000, 1.000)	(2.000, 2.500, 3.000)	(1.000, 1.500, 2.000)
Connectivity	(0.250, 0.333, 0.500)	(0.250, 0.333, 1.000)	(0.500, 1.000, 1.667)	(0.600, 0.833, 1.200)	(0.333, 0.400, 1.000)	(1.000, 1.000, 1.000)	(1.000, 1.200, 1.500)
Supplier and customer disruption	(0.333, 0.400, 0.500)	(0.222, 0.286, 0.400)	(0.400, 0.500, 0.667)	(0.333, 0.400, 0.667)	(0.500, 0.667, 1.000)	(0.667, 0.833, 1.000)	(1.000, 1.000, 1.000)

After applied pairwise comparison matric under each sub-criterion, operation of triangle fuzzy number is applied to find the value for each criterion if (a1, b1, c1) and (b1, b2, c2) is Triangular Fuzzy Numbers (Patil, 2018)

$$= (a1, b1, c1) + (a2, b2, c2) \quad (4.1)$$
$$= (a1+a2, b1+ b2, c1+ c2)$$

Turbulence

= (1+1+3+2+2+2+2, 1+1.8+5+3+3+3+2.5, 1+2.5+7+4+4+4+3)

= <u>(13, 19.3, 25.50)</u>

Deliberate threat

= (0.4+1+0.6+0.75+1+2+2.5, 0.556+1+0.8+1+1.2+3+
3.5, 1+1+1+1.25+1.5+4+4.5)

= <u>(8.25,11.056,14.25)</u>

External pressure

= (0.143+1+1+0.9+0.5+1.5+1.5,0.2+1.25+1+1.1+
0.667+1.8+2, 0.333+0.1667+1+1.3+0.833+2+2.5)

= <u>(6.543,8.017,9.633)</u>

Resource limits

= (0.25+0.8+0.769+1+1+0.833+1.5, 0.333+1+1.1+1+1.5+
1.2+2.5, 0.5+1.333+1.429+1+2+1.667+3.5)

= <u>(6.152,8.633,11.429)</u>

Sensitivity

= (0.25+0.667+1.2+2.5+1+2+1, 0.333+0.833+1.5+0.667+1+
2.5+1.5, 0.5+1+1.8+1+1+3+2)

= <u>(6.617, 8.333,10.30)</u>

Connectivity

= (0.25+0.25+0.5+0.6+0.333+1+1, 0.333+0.333+1+0.833+
0.4+1+1.2, 0.5+1+1.667+1.2+1+1+1.5)

= <u>(3.933,5.099,7.867)</u>

Supplier and customer disruption

= (0.333+0.222+0.4+0.333+0.5+0.667+1, 0.4+0.286+0.5+0.4+
0.667+0.833+1, 0.5+0.4+0.667+0.667+1+1+1)

= <u>(3.455,4.086,5.234)</u>

Next step, the fuzzy Synthetic Value (S_i) was calculated by using equation (4.2) below, the result of fuzzy Synthetic value for each sub-criterion respect to vulnerability is shown in table 4.4 below.

$$S_i = \sum^{m}{}_{j=1} M^j \text{ x } [\sum^{n}{}_{i=1} \sum^{m}{}_{j=1} M^j]$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} lij , \sum_{j=1}^{m} mij , \sum_{j=1}^{m} uij \right)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right] = \left(\frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} uij}, \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} mij}, \frac{1}{\sum_{n}^{i=1} \sum_{m}^{j=1} lij} \right) \quad (4.2)$$

Table 4.4 Fuzzy synthetic value for each sub-criterion of vulnerability

Criteria	Calculation	Result
Turbulence	(13, 19.3, 25.50) ⊗ (1/84.213,1/64.524,1/47.950)	(0.154, 0.299, 0.532)
Deliberate threat	(8.25,11.056,14.25) ⊗ (1/84.213,1/64.524,1/47.950)	(0.098, 0.171, 0.297)
External pressure	(6.152,8.017,9.633) ⊗ (1/84.213,1/64.524,1/47.950)	(0.078, 0.124, 0.201)
Resource limits	(6.152,8.633,11.429) ⊗ (1/84.213,1/64.524,1/47.950)	(0.073, 0.134, 0.238)
Sensitivity	(6.617, 8.333,10.30) ⊗ (1/84.213,1/64.524,1/47.950)	(0.079, 0.129, 0.215)
Connectivity	(3.933,5.099,7.867) ⊗ (1/84.213,1/64.524,1/47.950)	(0.047, 0.079, 0.164)
Supplier and customer disruption	(3.455,4.086,5.234) ⊗ (1/84.213,1/64.524,1/47.950)	(0.041, 0.063, 0.109)

After that, Fuzzy Synthetic value for each sub-criterion of vulnerability and respond capacity are used for calculating the degree of possibility in the next step by using equation (4.3) below when $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$. Result of the degree of possibility (V-Value) are shown in table 4.5 below.

$$V(M_2 \geq M_1) = \max(M_2 \cap M_1) = \mu(d) = \begin{cases} = 1 \text{ if } m_2 \geq m_1 \\ = 0 \text{ if } m1_2 \geq \mu_2 \\ = \dfrac{l1-u2}{(m2-u2)\,(m1-l1)} \text{ otherwise} \end{cases} \quad (4.3)$$

Table 4.5 Viscosity profile of SEDDS formulation

	Turbulence	**Deliberate threat**	**External pressure**	**Resource limits**	**Sensitivity**	**Connectivity**	**Supplier and customer disruption**
Turbulence	-	1	1	1	1	1	1
Deliberate threat	0.132	-	1	1	1	1	1
External pressure	-	0.313	-	0.85	0.905	1	1
Resource limits	-	0.567	1	-	1	1	1
Sensitivity	-	0.43	1	0.933	-	1	1
Connectivity	-	-	0.312	0.327	0.279	-	1
Supplier and customer disruption	-	-	-	-	-	0.562	-

The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i=1, 2, …, *k*) can be define by $V(M \geq M_1, M_2, \ldots, M_k = \min V(M \geq M_i)$ where i=1, 2, 3, …, k then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), .., d'(A_n))^T, \quad (4.4)$$

The weight vector for vulnerability were calculated using equation (9) from chapter 2 and the result are show below.

$$W' = (1.00, 0.132, 0.313, 0.567, 0.430, 0.279, 0.562)^T$$

The result of final weight for vulnerability are show below.

$$W = (0.305, 0.040, 0.095, 0.173, 0.131, 0.085, 0.171)$$

4.3 Consistency Ratio

4.3.1 Defuzzify the Fuzzy Pairwise Comparison Matrix of Vulnerability Factors

Table 4.6 The fuzzy pairwise comparison matrix of vulnerability factors

	Turbulence	**Deliberate threat**	**External pressure**	**Resource limits**	**Sensitivity**	**Connectivity**	**Supplier and customer disruption**
Turbulence	(1.000, 1.000, 1.000)	(1.000, 1.800, 2.500)/3	(3.000, 5.000, 7.000)/3	(2.000, 3.000, 4.000)/3	(2.000, 3.000, 4.000)/3	(2.000, 3.000, 4.000)/3	(2.000, 2.500, 3.000)/3
Deliberate threat	(0.400, 0.556, 1.000)/3	(1.000, 1.000, 1.000)	(0.600, 0.800, 1.000)/3	(0.750, 1.000, 1.250)/3	(1.000, 1.200, 1.500)/3	(2.000, 3.000, 4.000)/3	(2.500, 3.500, 4.500)/3
External pressure	(0.143, 0.200, 0.333)/3	(1.000, 1.250, 1.667)/3	(1.000, 1.000, 1.000)	(0.900, 1.100, 1.300)/3	(0.500, 0.667, 0.833)/3	(1.500, 1.800, 2.000)/3	(1.500, 2.000, 2.500)/3
Resource limits	(0.250, 0.333, 0.500)/3	(0.800, 1.000, 1.333)/3	(0.769, 1.100, 1.429)/3	(1.000, 1.000, 1.000)	(1.000, 1.500, 2.000)/3	(0.833, 1.200, 1.667)/3	(1.500, 2.500, 3.500)/3
Sensitivity	(0.250, 0.333, 0.500)/3	(0.667, 0.833, 1.000)/3	(1.200, 1.500, 1.800)/3	(0.500, 0.667, 1.000)/3	(1.000, 1.000, 1.000)	(2.000, 2.500, 3.000)/3	(1.000, 1.500, 2.000)/3
Connectivity	(0.250, 0.333, 0.500)/3	(0.250, 0.333, 1.000)/3	(0.500, 1.000, 1.667)/3	(0.600, 0.833, 1.200)/3	(0.333, 0.400, 1.000)/3	(1.000, 1.000, 1.000)	(1.000, 1.200, 1.500)/3
Supplier and customer disruption	(0.333, 0.400, 0.500)/3	(0.222, 0.286, 0.400)/3	(0.400, 0.500, 0.667)/3	(0.333, 0.400, 0.667)/3	(0.500, 0.667, 1.000)/3	(0.667, 0.833, 1.000)/3	(1.000, 1.000, 1.000)/3

The defuzzified matrix is:

$$A = \begin{bmatrix} 1 & 1.767 & 5.000 & 3.000 & 3.000 & 3.000 & 2.500 \\ 0.652 & 1 & 0.800 & 1.000 & 1.233 & 3.000 & 3.500 \\ 0.225 & 1.306 & 1 & 1.000 & 0.667 & 1.767 & 2.000 \\ 0.361 & 1.044 & 1.099 & 1 & 1.500 & 1.233 & 2.500 \\ 0.361 & 0.833 & 1.500 & 0.722 & 1 & 2.500 & 1.500 \\ 0.361 & 0.528 & 1.056 & 0.878 & 0.578 & 1 & 1.233 \\ 0.411 & 0.303 & 0.522 & 0.467 & 0.722 & 0.833 & 1 \end{bmatrix}$$

4.3.2 Calculate the Priority Vector (Eigenvector)

Normalize each column by dividing by the sum of the column, then calculate the average of each row.

Column sums = [3.371, 6.781, 9.878, 8.867, 8.700, 13.333, 14.233]

Normalized matrix A norm:

$$A_{norm}=\begin{bmatrix} 0.297 & 0.261 & 0.455 & 0.367 & 0.345 & 0.225 & 0.176 \\ 0.193 & 0.147 & 0.073 & 0.122 & 0.142 & 0.225 & 0.246 \\ 0.067 & 0.193 & 0.091 & 0.135 & 0.077 & 0.133 & 0.141 \\ 0.107 & 0.154 & 0.100 & 0.122 & 0.172 & 0.093 & 0.176 \\ 0.107 & 0.123 & 0.137 & 0.088 & 0.115 & 0.188 & 0.105 \\ 0.107 & 0.078 & 0.096 & 0.107 & 0.066 & 0.075 & 0.087 \\ 0.122 & 0.045 & 0.048 & 0.057 & 0.083 & 0.063 & 0.070 \end{bmatrix}$$

Calculate the priority vector by averaging each row:

$$\text{Priority vector} = \begin{bmatrix} \frac{0.296+0.261+0.455+0.367+0.345+0.225+0.176}{7} \\ \frac{0.193+0.147+0.073+0.122+0.142+0.225+0.246}{7} \\ \frac{0.067+0.193+0.091+0.135+0.077+0.133+0.141}{7} \\ \frac{0.107+0.154+0.100+0.122+0.172+0.093+0.176}{7} \\ \frac{0.107+0.123+0.152+0.088+0.115+0.188+0.113}{7} \\ \frac{0.107+0.078+0.096+0.107+0.066+0.075+0.087}{7} \\ \frac{0.122+0.045+0.048+0.057+0.083+0.063+0.070}{7} \end{bmatrix}$$

$$\text{Priority vector} = \begin{bmatrix} 0.304 \\ 0.164 \\ 0.119 \\ 0.132 \\ 0.123 \\ 0.088 \\ 0.070 \end{bmatrix}$$

4.3.3 Calculate the Weighted Sum Vector

$$\text{Weight sum vector=Priority vector=A}\begin{bmatrix} 1 & 1.767 & 5.000 & 3.000 & 3.000 & 3.000 & 2.500 \\ 0.652 & 1 & 0.800 & 1.000 & 1.233 & 3.000 & 3.500 \\ 0.225 & 1.306 & 1 & 1.000 & 0.667 & 1.767 & 2.000 \\ 0.361 & 1.044 & 1.099 & 1 & 1.500 & 1.233 & 2.500 \\ 0.361 & 0.833 & 1.500 & 0.722 & 1 & 2.500 & 1.500 \\ 0.361 & 0.528 & 1.056 & 0.878 & 0.578 & 1 & 1.233 \\ 0.411 & 0.303 & 0.522 & 0.467 & 0.722 & 0.833 & 1 \end{bmatrix}\begin{bmatrix} 0.304 \\ 0.164 \\ 0.119 \\ 0.132 \\ 0.123 \\ 0.088 \\ 0.070 \end{bmatrix}$$

$$\text{Weight sum vector} = \begin{bmatrix} 2.394 \\ 1.249 \\ 0.924 \\ 1.012 \\ 0.969 \\ 0.683 \\ 0.530 \end{bmatrix}$$

4.3.4 Calculateλmax

Divide the weighted sum vector by the priority vector and average the result:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{\text{Weighted sum vector}_i}{\text{Priority vector}_i}$$

$$\lambda\text{max} = \frac{1}{7}(7.884 + 7.612 + 7.749 + 7.662 + 7.857 + 7.755 + 7.623)$$

$$\lambda\text{max} = \frac{54.142}{7} = 7.735$$

4.3.5 Calculate the Consistency Index (CI)

According to vulnerability, calculation of the Consistency Index (CI) is shown below

$$\text{CI} = \frac{7.735\text{-}7}{7\text{-}1} = \frac{0.735}{6} = 0.1225$$

According to respond capacity, calculation of the Consistency Index (CI) is shown below

$$\text{CI} = \frac{7.80\text{-}7}{7\text{-}1} = \frac{0.80}{6} = 0.133$$

4.3.6 Calculate the Consistency Ratio (CR)

$$CR = \frac{CI}{RI}$$

Where RI (Random Index) depends on the number of elements for vulnerability, n. For n=7, RI=1.32

$$CR = \frac{0.1225}{1.32} = 0.09$$

Where RI (Random Index) depends on the number of elements for respond capacity, For n=7, RI=1.32

$$CR = \frac{0.133}{1.32} = 0.10$$

According to Saaty (1994) To ensure the reliability of these comparisons, the Consistency Ratio (CR) is used. The CR measures how consistent the pairwise comparisons are by comparing them to randomly generated matrices of the same size. It is calculated by dividing the Consistency Index (CI), which measures the deviation of the principal eigenvalue from the number of criteria, by the Random Consistency Index (RI) in Table 3.1, with a CR value of 0.1 or less is generally considered acceptable, indicating that the comparisons are consistent enough for reliable decision-making.

Table 4.7 Final ranking of factors respect to vulnerability

Rank	Sub-criterion	Normalized weight
1	Turbulence	0.305
2	Resource limits	0.173
3	Supplier and customer disruption	0.171
4	Sensitivity	0.131
5	External pressure	0.095
6	Connectivity	0.085
7	Deliberate threat	0.040

According to Table 4.6, the final ranking result of the factor with respect to vulnerability was established. The result found that Turbulence (0.305) is identified as the most significant factor in the context of coffee roastery with respect to vulnerability. Deliberate threat (0.040) is identified as the last rank of factors with respect to vulnerability. Turbulence (0.305) refers to the inherent volatility and unpredictability within the coffee roasting industry. Factors like fluctuating coffee bean prices, changing consumer preferences, and unexpected weather events can disrupt the smooth flow of operations. A high weight for Turbulence indicates a need for coffee roasters to be adaptable and have contingency plans to navigate these uncertainties. Deliberate Threat (0.040) This sub-criterion focuses on intentional disruptions to the supply chain, such as cyberattacks, sabotage, or political instability in coffee-producing countries. A high weight for this factor suggests that coffee roasters should invest in cybersecurity measures, diversify their sourcing options, and stay informed about potential geopolitical risks. Resource Limits (0.173) This highlights the limitations in resources, such as finances, skilled labor, or storage capacity, that can hinder a roaster's ability to respond to disruptions. A high weight for this factor indicates a need for coffee roasters to optimize resource allocation, explore outsourcing options, and potentially secure financing to overcome resource constraints during disruptions. Sensitivity (0.131) refers to how susceptible a coffee roaster's operations are to disruptions. Factors like dependence on a single supplier, reliance on just-in-time inventory management, or lack of automation can all increase sensitivity. High weight for sensitivity suggests that coffee roasters should diversify their supplier base, build buffer stocks, and invest in automation to create a more robust system. Connectivity (0.085) This sub-criterion focuses on the efficiency and reliability of information flow within the supply chain. Strong communication channels with suppliers, distributors, and logistics providers are crucial for proactive response during disruptions. A high weight for connectivity indicates that coffee roasters should invest in communication technology, build strong relationships with partners, and establish clear information-sharing protocols. External Pressure (0.095) refers to external forces beyond a coffee roaster's direct control, such as government regulations, trade policies, or environmental changes. Adapting to these external pressures can be crucial for long-term resilience. A high weight for this factor suggests that coffee roasters should stay updated on regulatory changes, explore sustainable sourcing practices, and potentially advocate for policies that support a resilient coffee supply chain. Supplier and Customer Disruption (0.171) This sub-criterion highlights the impact of disruptions suppliers or customers face. For example, a supplier bankruptcy or a major customer experiencing financial difficulties can affect a coffee roaster's operations. A high weight for this factor suggests that coffee roasters should develop strong relationships with suppliers and customers, diversify their supplier base and portfolio, and potentially have contingency plans to mitigate such disruptions' impact. The method for analyzing is applied to response capacity in the same way. The results for response capacity are shown in Table 4.8 below.

Table 4.8 Pairwise comparison matric respect to respond capacity

	Flexible in sourcing	Flexible in order fullfillment	Capacity	Effiency	Visibility	Adaptability	Anticipation
Flexible in sourcing	(1, 1, 1)	(1.5, 2.5, 3.5)	(2.5, 3.5, 4.5)	(4, 5, 6)	(3, 4.5, 5.5)	(5, 6, 7)	(2, 3.5, 4.5)
Flexible in order fullfillment	(0.333, 0.4, 0.667)	(1, 1, 1)	(1.8, 2.7, 3.8)	(2.2, 3.3, 4.5)	(1.6, 2.7, 3.8)	(3, 4.5, 5.5)	(2.5, 3.5, 4.5)
Capacity	(0.222, 0.286, 0.4)	(0.263, 0.37, 0.556)	(1, 1, 1)	(1.3, 2.2, 3)	(2.7, 3.5, 4.5)	(1.8, 2.5, 3.5)	(2.2, 3.3, 4.5)
Effiency	(0.167, 0.2, 0.25)	(0.222, 0.303, 0.455)	(0.333, 0.455, 0.769)	(1, 1, 1)	(2.3, 3.2, 4.2)	(1.5, 2.3, 3)	(3.3, 4.3, 5.5)
Visibility	(0.182, 0.222, 0.333)	(0.263, 0.37, 0.625)	(0.222, 0.286, 0.4)	(0.238, 0.313, 0.435)	(1, 1, 1)	(2.5, 3.7, 5)	(1.7, 2.8, 4.2)
Adaptability	(0.143, 0.167, 0.2)	(0.182, 0.222, 0.333)	(0.333, 0.4, 0.556)	(0.333, 0.435, 0.667)	(0.2, 0.278, 0.4)	(1, 1, 1)	(3.3, 4.2, 5.5)
Anticipation	(0.222, 0.286, 0.5)	(0.286, 0.4, 0.667)	(0.222, 0.303, 0.455)	(0.182, 0.238, 0.303)	(0.238, 0.357, 0.588)	(0.182, 0.238, 0.303)	(1, 1, 1)

Table 4.9 Fuzzy synthetic value for each sub-criterion of respond capacity

Criterion	Calculation	Result
Flexible in sourcing	(19,26,32) ⊗ (1/112.85,1/87.429,112.862)	(0.168,0.297,0.511)
Flexible in order fulfillments	(12.433,18.1,23.767) ⊗ (1/112.85,1/87.429,112.862)	(0.011,0.207,0.373)
Capacity	(9.485,13.156,17.456) ⊗ (1/112.85,1/87.429,112.862)	(0.084,0.15,0.274)

Table 4.9 (continued)

Criterion	Calculation	Result
Efficiency	(8.822,11.758,15.174) ⊗ (1/112.85,1/87.429,112.862)	(0.078,0.134,0.238)
Visibility	(6.105,8.691 ,11.993) ⊗ (1/112.85,1/87.429,112.862)	(0.054,0.099,0.188)
Adaptability	(5.491,6.702,8.656) ⊗ (1/112.85,1/87.429,112.862)	(0.048,0.077,0.136)
Anticipation	(2.332,3.022,3.816) ⊗ (1/112.85,1/87.429,112.862)	(0.021,0.035,0.059)

Table 4.10 Degree of possibility (V-Value) for each sub-criterion of respond capacity

	Flexible in sourcing	Flexible in order fullfillment	Capacity	Effiency	Visibility	Adaptability	Anticipation
Flexible in sourcing	-	1	1	1	1	1	1
Flexible in order fullfillment	0.80	-	1	1	1	1	1
Capacity	0.70	1	-	1	1	1	1
Effiency	0.60	0.8	1	-	1	1	1
Visibility	0.50	0.7	0.8	1	-	1	1
Adaptability	0.40	0.6	0.7	0.8	1	-	1
Anticipation	0.30	0.5	0.6	0.7	0.8	1	-

The weight vector for respond capacity were calculated using equation (2.9) from chapter 2 and the result are show below.

W' = (1.00, 0.80, 0.70, 0.60, 0.50, 0.40, 0.30) T

The result of final weight for respond capacity are show below.

W = (0.233, 0.186, 0.163, 0.140, 0.116, 0.093, 0.070)

Table 4.11 Final ranking of factors respect to respond capacity

Rank	Sub-criterion	Normalized weight
1	Flexible in sourcing	0.233
2	Flexible in order fulfillments	0.186
3	Capacity	0.163
4	Efficiency	0.140
5	Visibility	0.116
6	Adaptability	0.093
7	Anticipation	0.070

According to table 4.10 the final ranking result of factor respect to respond capacity was established. Base on the ranking within the context of coffee roastery. Flexible in sourcing (0.102) is identified as the most important priorities factor respect to respond capacity. Anticipation (0.070) is identified as the last rank respect to respond capacity.

Flexible in sourcing (0.102) refers to a roaster's ability to adapt its sourcing strategies in response to challenges. Having multiple reliable suppliers, the ability to source from different origins, and exploring alternative bean types all contribute to sourcing flexibility. A high weight for this factor suggests that coffee roasters should diversify their supplier base and avoid over-reliance on any single source. Efficiency (0.140) this sub-criterion highlights the importance of streamlined operations throughout the supply chain. Efficient roasting, packaging, and logistics processes can minimize waste and allow quicker response times during disruptions. A high weight for efficiency suggests that coffee roasters should invest in optimizing their operations, potentially through automation or lean manufacturing techniques. Flexible order fulfillment (0.186) is a valuable strategy for businesses of all sizes. By carefully considering the benefits and challenges, businesses can develop a flexible fulfillment strategy that meets their needs and helps them deliver a superior customer experience. Capacity (0.163) this refers to the roaster's ability to handle fluctuations in demand or supply. Having adequate storage space, production capacity, and a skilled workforce are crucial for maintaining operations during disruptions. A high weight for capacity suggests that coffee roasters should assess their production capabilities and consider buffer stocks or flexible production schedules to adapt to changing circumstances. Adaptability (0.093) this sub-criterion focuses on the roaster's ability to adjust strategies and processes in response to unexpected events. A flexible organizational structure, a culture of innovation, and a willingness to experiment with new solutions are all signs of adaptability. A high weight for adaptability suggests that coffee roasters should encourage a culture of continuous improvement and empower employees to find creative solutions during disruptions. Visibility (0.116) the roaster can track and monitor their supply chain in real time. Good inventory management systems, strong communication with suppliers, and access to market data can all increase visibility. A high weight for visibility suggests that coffee roasters should invest in technology solutions that provide real-time data on inventory levels, supplier performance, and market trends. Anticipation (0.070) this sub-criterion highlights the roaster's ability to forecast potential disruptions and plan mitigation strategies. Market research, monitoring weather patterns, and staying informed about geopolitical risks can all contribute to anticipation. A high weight for anticipation suggests that coffee roasters should conduct scenario planning, develop contingency plans for different disruption scenarios, and stay updated on industry trends.

4.4 Recommendation

In another discussion, according to the results, it is essential to highlight the significance of Turbulence and flexible sourcing within the context of supply chain resilience for coffee roasteries. According to table 4.6 Turbulence, as the top-ranked factor in vulnerability, represents the unpredictable and disruptive nature of external factors, such as market fluctuations, supply chain disruptions, and regulatory changes Pettit, Fiksel, and Croxton (2010) which can significantly impact the operations and performance of coffee roastery businesses. Recognizing and addressing Turbulence requires strategies and planning to adapt quickly to changing circumstances. In further discussion, it is essential to emphasize the implications of prioritizing Turbulence as the primary concern within the vulnerability dimension.

According to table 4.10 the importance of flexible sourcing in response capacity cannot be overstated. It underscores the need for adaptability and agility in responding to Turbulence. The ability to quickly adjust sourcing strategies based on market conditions, supplier availability, and other factors is critical for maintaining a reliable supply chain and meeting customer demands.

The findings suggest that coffee roastery businesses' resilience depends not only on their ability to address specific vulnerabilities but also on their overall capacity to respond to unforeseen events and challenges. Therefore, practitioners should adopt a holistic approach to supply chain resilience, considering both vulnerability and response capacity factors in their strategic planning and decision-making processes.

In essence, prioritization lies at the heart of enhancing supply chain resilience for coffee roasteries, with turbulence emerging as the primary concern. Following turbulence are deliberate threats, sensitivity, resource limits, connectivity, external pressure, and disruptions from suppliers and customers. The focus areas revolve around sourcing flexibility, efficiency, order fulfillment, and capacity. Factors such as adaptability, visibility and anticipation are essential to fortify this approach. Ultimately, this strategy equips coffee roasteries with a well-rounded approach to enhance their response capacity and resilience, enabling them to navigate disruptions effectively and maintain operational stability.

CHAPTER 5

CONCLUSION

5.1 Discussion and Conclusion

This study selects Fuzzy AHP to weigh the resilience factors influencing coffee roastery. It ranks the significant factors under the vulnerability and response capacity dimension to find the valuable factors that support the supply chain resilience concept. The factors, which include two related sizes, influence coffee roaster businesses in the northern Thailand to resist and respond to unpredictable events and possible disruption. From the result, seven factors under the vulnerability dimension are selected and prioritized through the fuzzy AHP approach.

5.1.1 Addressing Objective One and Objective 2

Firstly, significant factors that influence coffee roasters in the northern region of Thailand were established in this research based on a literature review and in-depth interviews with experts working and running the coffee roastery business in the northern region. After the interviews for validation, two main dimensions, vulnerability, and response capacity, were used to form the main structure. These were discussed in the content in Chapter 2, and we found that seven factors under vulnerability

and seven factors under the response capacity dimension were established. The other factors that are not included are not currently applied due to the situation and operation of the coffee roastery based on the perspective of experts.

5.1.2 Addressing Objective 3

This research used the Fuzzy AHP method to analyze the data collected from experts. The finding showed that under the vulnerability dimension, the most influential is Turbulence, with a weight of (0.305), which is the priority to be concerned, followed by Resource limits (0.173), Supplier and customer disruption (0.171), Sensitivity (0.131), External pressure (0.095), Connectivity (0.085), Deliberate threat (0.040). Under the response capacity dimension, for the final ranking, the most significant criterion is Flexible in sourcing, with a weight of (0.233), follow by Flexible in order fulfillment (0.186), Capacity (0.163), Efficiency (0.140), Visibility (0.116), Adaptability (0.093), Anticipation (0.070).

5.1.3 Addressing Objective 4

The finding from the Fuzzy AHP result benefits the person who has to run the operation related to the coffee roaster business. Moreover, the result from this prioritization indicates a comprehensive approach to resilience strategy. Practical strategies and planning for each factor can contribute to the resiliency of the coffee roaster business, and prioritization emphasizes a comprehensive approach to response capacity. Furthermore, the result can be applied to develop a strategy to control the risk and resist any future disruption and unpredicted events we cannot predict.

5.2 Limitation and Future Research

The study's findings are specific to coffee roasteries in northern Thailand and may not apply to other regions or industries. Using the Fuzzy Analytical Hierarchy Process (AHP) method to prioritize factors introduces subjectivity, as it relies on experts' opinions that could be biased. Additionally, the study's focus on a specific time may overlook changes affecting supply chain resilience over time. Businesses, especially coffee roasters in northern Thailand, should consider integrating the prioritized factors into their risk management and resilience strategies. Further research should explore how these factors interact and conflict with each other better to understand their combined impact on overall supply chain resilience.

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APPENDICES

APPENDIX A

SURVEY QUESTIONAIRE

Part 1: Demographic of participants

1. Age
   - ☐ Under 21 years old
   - ☐ 21–35 years old
   - ☐ 36-50 years old
   - ☐ 51-64 years old
   - ☐ 65 years old or older

2. Sex
   - ☐ Male
   - ☐ Female
   - ☐ Not specifies.

3. Company name

………………………………………………………………………………………………

4. Working experience (years)
   - ☐ 1-3 years
   - ☐ 2-4 years
   - ☐ More than 5 years

5. Position

………………………………………………………………………………………………

Part 2: Question used in the interview.

1. What are the most significant threats that the coffee roastery is currently facing? How are these threats impacting the business?
   Answer: The rising prices of raw coffee beans lead to higher roasting costs. Climate volatility affects crop yields, impacting the supply chain's stability.

2. Are there any environmental risks or threats that could impact the roastery's supply chain, such as weather events or natural disasters in coffee-producing regions?
   Answer: This situation primarily affects upstream suppliers, causing fluctuations in coffee prices.

3. Have there been any recent disruptions or delays in the supply chain that have impacted the roastery's operations or profitability?
   Answer: The quality of raw coffee beans decreases, but prices rise. Insufficient supply of quality beans forces the use of more expensive alternatives.

4. Are there any financial risks or threats that could impact the roastery's supply chain, such as fluctuations in exchange rates or supplier bankruptcy?
   Answer: Due to volatile coffee prices, small processors cannot supply beans to small businesses, often being tied to larger companies offering better prices.

5. Have there been any changes in technology or equipment used in coffee roasting that may affect the efficiency or effectiveness of the operation?
   Answer: Continuous improvements in equipment types and brands enhance product quality. New technologies make the coffee roasting process more stable and improve overall quality.

6. Are there any labor issues or shortages that may impact the production or distribution of coffee?

   Answer: There is no significant impact on labor requirements as coffee roasting operations do not require a large workforce.

7. Are there any social or cultural factors that may impact the demand for coffee or the perception of the coffee roastery brand?

   Answer: Evolving coffee trends and consumer behavior necessitate a clear brand identity to stay relevant.

8. Are coffee productivity impact your roastery?

   Answer: Volatility in raw material prices significantly affects the inputs for roasting operations.

9. How vulnerable is the coffee roastery's supply chain to environmental risks, such as natural disasters or extreme weather events that could disrupt transportation or cause damage to facilities?

   Answer: While not directly impacting roasters, it greatly affects upstream suppliers who are the primary source.

10. Are there any risks associated with the availability or reliability of labor within the supply chain, such as labor shortages, strikes, or other disruptions?

    Answer: The skills of the roasters and fluctuations in the labor market play a crucial role.

11. What are the potential vulnerabilities in your roastery?

    Answer: There is a lack of suppliers, price volatility and productivity yield affecting the supply chain.

12. Do you have any backup suppliers to support your coffee bean source? Is it necessary?

    Answer: Yes, maintaining strong relationships with suppliers is crucial.

13. Are coffee productivity impact your roastery?

    Answer: Volatile conditions of productivity yield directly affect the coffee roasting business.

14. Are there have any external pressure or something that create business constraints or barriers? (Such as regulatory or legal.)

    Answer: Yes, Legal restrictions on importing coffee and the dominance of large investors pose significant challenges.

15. Dose limit of resource impact on your roastery?

    Answer: Changes in trends directly affect the raw materials and equipment used in coffee roasting.

16. what do you think about importance of carefully control conditions for product and process integrity?

    Answer: Consistency from upstream to downstream is essential for maintaining quality.

17. what do you think about how importance of interdependence and reliance on outside entities?

    Answer: Cooperation and mutual support are vital for advancing and developing the Thai coffee industry.

18. Are there any risks associated with the reputation of the coffee roastery or roastery's suppliers?

    Answer: The quality of raw coffee beans varies each year, impacting the quality of roasted coffee.

19. Have you ever experienced any customer and supplier's disruptions?

    Answer: Inconsistent quality from suppliers and halted orders from customers pose significant challenges.

20. In term of logistic and supply chain, in your opinion what are the potential capability in roastery?

    Answer: Efficient inventory management to ensure a steady supply of beans and build strong relationships with reliable suppliers to maintain quality and consistency.

21. Do you have any backup suppliers to support your coffee bean source?

    Answer: Having enough reliable backup suppliers, the roastery can maintain consistent production levels and quality, even in the face of unforeseen circumstances affecting their primary suppliers

22. Do you have any flexible fulfillment options?

    Answer: The roastery effectively responds to customer needs through various channels such as Shopee, Line Shop, website, Facebook, and Instagram. This multi-channel approach allows the business to reach a wider audience, enhance customer engagement, and facilitate convenient purchasing options for customers.

23. How about the availability of coffee bean to productivity is it important?

    Answer: Yes, it is crucial for maintaining consistent production levels and ensuring product quality.

24. Do you think knowledge of roasting and operating asset are necessary?

    Answer: Yes, it is very necessary, knowledge of roasting techniques and operating equipment is essential for ensuring the quality and consistency of the coffee

25. In your opinion how important about ability to modify operations in response to challenges or opportunities and ability to discern potential future events?

    Answer: Being prepared for future problems and events is crucial for the sustainability and resilience of the business. Proactive planning and risk management allow the business to quickly adapt to unforeseen challenges, minimize disruptions, and maintain continuous operations.

26. If any disruption impacts your company, do you think recovery potential are necessary? why?

    Answer: Yes, and it is necessary. We must enable effective responses to supply chain issues, market changes, ensuring continuous operation and we must ensure minimal downtime and quick restoration of coffee roasting operations. Moreover, to keeps customer confidence by ensuring the quality and consistency of product.

27. How important of collaboration for the coffee roastery?

    Answer: Yes, community is key for improving. Sharing knowledge and collaborating within the community are vital for continuous improvement and innovation.

28. How about the important of organization in your opinion whatever human resource structure policies or skill and culture?

    Answer: It is crucial for efficiency, employee satisfaction, and achieving business goals

29. How important for capacity to absorb fluctuation in cash flow?

    Answer: The business is operated with low overhead cost, make it easier to manage cash flow. They no need to hire a lot of worker and green coffee bean can storage for 6-12 months.

30. How important about security in the coffee roastery?

    Answer: Ensuring food safety and maintaining a safe working environment in the factory are critical for the success and reputation of the business

APPENDIX B

FUZZY AHP SURVEY

INSTRUCTION

The questionnaire is designed based on scale of preference with value from 1 to 9 to rate relative priorities of two criteria at a time. A criterion is compared to other criteria at a time (Pairwise comparison) in determining which of them will impact and valuable. **The pairwise comparison scale are shown in table B1.**

The degree of occurrence one criterion has to the other is arranged on the right and left-hand side of criterion 1 and criterion 2 if you believe the factor in (...) are strongly than the other one, you can mark it (1) to (9) based on the pairwise comparison scale. However, if you believe the other one factor are important than the factor in (...) you can also mark the number 1 to 9 on the right-hand side.

However, suppose you think that the two criterions are both likely to be of equally important. In that case you are expected to mark 1 on the center option i.e., **1= equally important**

By following the same procedure, you are requested to kindly complete the pairwise comparison of different conditioning factors.

Table B1 Pairwise comparison scale

	Linguistic variables	L	M	U
9	Extreme importance	9	9	9
8	Very strong to extreme importance	7	8	9
7	Very strong importance	6	7	8
6	Strong to very strong importance	5	6	7
5	Strong importance	4	5	6
4	Moderate to strong importance	3	4	5
3	Moderate importance	2	3	4
2	Equal to moderate importance	1	2	3
1	Equally importance	1	1	1

Vulnerability																		
Factor	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Factor**
Turbulence																		Deliberate Threat
																		External Pressure
																		Resource Limits
																		Sensitivity
																		Connectivity
																		Supplier and Customer disruption
Deliberate Threat																		External Pressure
																		Resource Limits
																		Sensitivity
																		Connectivity
																		Supplier and Customer disruption
External pressure																		Resource Limits
																		Sensitivity
																		Connectivity
																		Supplier and Customer disruption
Resource Limits																		Sensitivity
																		Connectivity
																		Supplier and Customer disruption
Sensitivity																		Connectivity
																		Supplier and Customer disruption
Connectivity																		Supplier and Customer disruption

Respond Capacity																		
Factor	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Factor**
Flexible in sourcing																		Flexible in order fulfillments
																		Capacity
																		Efficiency
																		Visibility
																		Adaptability
																		Anticipation
Flexible in order fulfillments																		Capacity
																		Efficiency
																		Visibility
																		Adaptability
																		Anticipation
Capacity																		Efficiency
																		Visibility
																		Adaptability
																		Anticipation
Efficiency																		Visibility
																		Adaptability
																		Anticipation
Visibility																		Adaptability
																		Anticipation
Adaptability																		Anticipation

APPENDIX C

PUBLISHED PAPER

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A STUDY ON THE RESILIENCY OF COFFEE ROASTER BUSINESS IN NORTHERN THAILAND REGION

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***Abstract*—Today's coffee shop and coffee roastery businesses are more mushrooming from the past. The coffee supply chain in Thailand, especially in the northern region, produces the most Arabica coffee in the country. In the last few years, the demand and coffee consumption volume has been higher than the output, and any disruption at any stage can directly impact the firm. This paper aims to prioritize the significant factors by using the fuzzy analytic hierarchy process (Fuzzy AHP) method based on the supply chain resilience concept under two dimensions, vulnerable and respond capacity, characteristic of supply chain resilience. This article will help researchers to understand the resilience concepts by prioritizing factors that influenced the coffee roastery and any related field under the supply chain resilience concept to prepare and resist possible disruption and unpredicted events.**

Keywords*—resiliency, fuzzy AHP, coffee roaster, supply chain resilience

I. INTRODUCTION

Coffee roasteries play a crucial role in the coffee supply chain. They transform green coffee beans into aromatic and flavorful beans that we enjoy in our cups of coffee. To ensure the smooth operation of coffee roasteries and maintain a consistent supply of high-quality coffee. The Thai coffee industry is growing in a positive direction within the country. This result will benefit the coffee industry to develop and improve its potential to compete with its competitors and satisfy demand within the country or drive the economy in the agricultural sector. The supply chain management is the key driver in the coffee industry from upstream to downstream, representing different activities and stakeholders. Like any other supply chain, the coffee supply chain can face disruption and challenges that impact its operations. The concept of supply chain resilience refers to the ability of a supply chain to withstand and recover from such disorders while maintaining its essential functions.

Moreover, firms should develop resilience strategies to improve supply chain resilience. Coffee roasteries must identify and assess potential risks that could disrupt their operation. The factors that influence the coffee roaster business play significant roles in the coffee supply chain due to their potential to disrupt operations and impact the availability and quality of coffee.

II. SUPPLY CHAIN RESILIENCE

Supply chain resilience (SCR) has emerged as a subfield in supply chain risk management (SCRM) literature and has become more critical in the past decade. According to [1], the paper provides a comprehensive review of the quantitative models for supply chain resilience, which can be helpful for researchers and practitioners in supply chain management. The paper's practical implications can help organizations build more resilient and sustainable supply chains, improving their ability to withstand disruptions and achieve long-term success. According to [2], supply chain resilience is the ability of a supply chain system to reduce the emergence of mistakes, errors, or disruptions in the supply chain and organization to reduce the outcome of those disruptions when they occur, and to reduce the time to recovery existing performance. Reference [3] concluded that supply chain resilience theory is about how to maintain when facing disruptions. Supply chains play an essential economic role by providing goods and services in many industries, such as food, logistics, transportation, and mobility. In the supply chain, resilience ensures operations are likely to avoid disruption. Disruption and crisis are linked to the resilience of the supply chain. In the study of [4], they concluded that supply chain resilience is the ability to prepare and recover for unforeseen events, risks, or disruptions that affect the supply chain performance to increase customer satisfaction, market share, and financial performance. Disruption can occur from external and internal sources in terms of the supply chain, disruption effect either upstream or downstream of the supply chain. Enable and maintain the operation to resist disruption; the resilience concept can be advantageous. Supply chain from different sectors that faced troubles for example manufacturing, automobile, food, chemical, electronic etc. Resilience in companies is essential and involves individuals, groups, and subsystems, [5].

Focus on roastery, which is manufacturers as represented in Table 1, [6] identified factors with definitions and sub-factors for each element to provide the knowledge of indicators that are encouraged to increase supply chain resilience performance and consolidate the wide range of literature on supply chain disruption to identify supply chain vulnerabilities and respond capacity factors.

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