RISK ANALYSIS OF RICE SUPPLY CHAIN IN CAMBODIA

BUNHORNG RATH

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR DOCTOR DEGREE OF PHILOSOPHY
IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT
FACULTY OF LOGISTICS
BURAPHA UNIVERSITY
2022

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การวิเคราะห์ความเสี่ยงในห่วงโซ่อุปทานข้าวกรณีศึกษาประเทศกัมพูชา

BUNHORNG RATH

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BUNHORNG RATH : RISK ANALYSIS OF RICE SUPPLY CHAIN IN CAMBODIA. ADVISORY COMMITTEE: THITIMA WONGINTA, Ph.D., CHOMPOONUT AMCHANG, Ph.D. 2022.

Rice is integral to Cambodia, yet farm households face many risks. The primary aim of this study is to analyze the risks facing the Cambodian rice supply chain. The study focuses on three specific objectives, 1) identifying the agricultural risk factors in the rice supply chain; 2) investigating risk factors that affect rice supply chain performance; 3) proposing risk management strategies in the sustainable rice supply chain management. The first qualitative area of exploration from this exploratory sequential design was to identify the potential risks, in which the researchers conducted in-depth interviews with 10 different experts in Cambodia. Using the structural equation model (SEM) in Amos and descriptive statistics analysis, this study investigated the risks that affect the rice supply chain performance on an environmental, social, and economic basis, and subsequently proposed risk management strategies. The researchers collected quantitative data from 200 Cambodian farmers through interviews and surveys.

The results illustrate that the farm households face 18 risk factors. The researchers consolidate 18 risk factors into four classifications: supply risks, production risks, demand risks, and environmental risks. Nine experts out of the 10 who were interviewed (90%) consider themselves “highly vulnerable” (with a rating of 4 or 5 on the Likert scale), while only 1 expert has a “neutral” stance (with a rating of 3 on the Likert scale); these results concerning risk identification are visualized in the likelihood-effect-matrix of the rice supply chain. After investigating the risks, the researchers found that rice supply chain performance is significantly affected by the rice supply chain risks. In particular, four groups are created, representing two different approaches to mitigate, avoid, transfer, and cope with agricultural risks, i.e., ex-ante and ex-post risk management strategies. This study fully answers research questions regarding risk identification, risk investigation, and risk management. Due to many risks in the Cambodian rice supply chain, there exists an urgent need to pay additional attention to these matters.

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Bunhorng Rath

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1
INTRODUCTION

Over the last few years, the economies of Asia (including China, India, Japan, and South Korea) have boasted the fastest growing economies by shifting the economic powers from the American or the western system to Asia. East Asian countries have experienced rapid growth since the 1960s (Shah, 2019). However, Asian Development Bank (2018) stated that the vast majority of the world's poor and hungry, that is, 64 percent or approximately 520 million people, live in Asia. They still live in rural areas and rely primarily on agricultural activities for their livelihood and income. Moreover, Asia increasingly encounters challenges, including degradation of natural resources, climate change, food security, and diet variability. According to World Bank (2016), risks are the primary cause and as a result, millions of households in the developing world face temporary food insecurity and abject poverty. In addition, risks destroy supply chains inherently and ubiquitously, and one severe outcome is that stakeholders and consumers face economic and financial losses. The levels of agricultural risk are diversified between and within countries, where developing countries and highly agriculture-dependent countries are more vulnerable to agricultural threats. Management of risks is an important task (World Bank, 2016).

In the Angkorian Civilization/ Khmer Empire from the ninth to the fourteenth centuries AD, great temples (including the Angkor Wat Temple) (Miksic & Yian, 2016; Nesbitt, 1997), a large irrigation system, and an extensive agriculture network (Arias et al., 2012) were constructed. After the seventeenth century, the Cambodian population and rice production faced turmoil, including war, conflict, and violence. Cambodia was in the nineteenth and into the twentieth centuries under French Colonial rule, from 1863 to 1953, and the French generated revenue from the Cambodians by taxing the rice (Nesbitt, 1997). In the subsequent phase, that is, 1970-1985, wars and political instability marked the country, negatively affecting the economy and devastating Cambodian rice exports right up to the 1990s (Cosslett & Cosslett, 2018; Dijkstra, 2019).

Agriculture is integral to Cambodia (a low-income country) (Chung et al., 2019), yet Cambodia's agricultural industry faces many challenges, constraints, and risks (Asian Development Bank, 2014; Dalgliesh et al., 2016; Eliste & Zorya, 2015; Mao et al., 2014; Mishra, Bairagi, et al., 2018; Sithirith, 2017; Stewart, 2018). Thirty-seven percent of Cambodia's GDP depends on agriculture, and 70 percent of the workforce relies on agriculture; and about 80 percent of farmers grow rice. On a positive note, Cambodia has since 2000 been successfully self-sufficient regarding rice production; although pockets of deficits still exist (Stewart, 2018). There remain challenges in Cambodian agriculture. A huge share of the past agricultural increase was driven by farmland expansion. The expansion of agricultural land has contributed to accelerated deforestation, especially in upland areas. On the other hand, farmers could not increase their income substantially because they un-changed agricultural land. Also, poverty was alleviated significantly, but the number of vulnerable people in Cambodia still rose significantly. Vulnerability proves the most significant among the smallest farms. Furthermore, the kingdom exported almost all crops to neighboring countries without processing them in the agro-processing industry. This reveals a weaknesses in supply chain management (raw material collection, finance, logistics, transport, storage, and information) (Eliste & Zorya, 2015). For instance, the Royal Government of Cambodia planned at least 1 million ton of rice export in 2015, but the kingdom did not achieve the goal; in fact, the 2015 measurement for exported rice product was only 538,396 tons in 2015 (Bunnarith, 2016). Rice farming in Cambodia is also vulnerable to climate change (drought and floods) (Dalgliesh et al., 2016; Mishra, Bairagi, et al., 2018). Moreover, Cambodia has abundant water resources in the rainy season but faces water scarcity in the dry season. This poses an enormous problem in long-term development (Sithirith, 2017). As claimed by the Cambodian government, rural and agricultural development—including rice production development—, is a priority in the national strategic development plan for poverty alleviation and economic growth (Chung et al., 2019).

Battambang, Cambodian Rice Basket, is one of the largest rice-producing areas in Cambodia (Bunthan et al., 2018). Even though hazardous weather affected farmers adversely, it was still the third-largest rice producer behind Prey Veng province and Takeo province in 2015 (Top & So, 2016). These figures indicate one side of the success story of supply chain performance concerning the stakeholders who benefited from it. The other side of the success story is to analyze the risks in the rice supply chain in Battambang, which the researcher would like to explore.

Since there is a lack of current research and insufficient information regarding this situation in Cambodia, given this opportunity, the researcher believes it is also essential to analyze the risks in the rice supply chain that play a significant role in the country. Therefore, the research herein is designed to fill this gap. The result of this scientific research will be helpful for the farming community, the national government, commercial institutions, academics, and all other stakeholders along the rice supply chain, including non-profit organizations (NGOs), development agencies, and various other parties. The importance of this research includes providing the knowledge connected with an enduring common practice, applying theories, making the generalizations, applying advanced methodology, evaluating a specific practice in Cambodia, and exploring new innovations for rice supply chain management. Also, it is beneficial for stakeholders to know the risks, the advantages of risk management, and the effective utilization of this academic study into practical activities.

Objectives and purposes of the study

The researcher of this study chose this topic with the following objectives:

1. To identify the agricultural risk factors in the rice supply chain (RSC)
2. To investigate risk factors that affect to rice supply chain performance
3. To propose risk management strategies in the sustainable rice supply chain management

Research question

Given the circumstances of the stakeholders in the research area, as well as the supply chain condition they are in, this science research will attempt to discover the answers to the three main research questions:

1. What are the agricultural risk factors in the rice supply chain?
2. What are the effects of risk factors on rice supply chain performance?
3. What actions should stakeholders take to manage risks in the RSC?

The proposed conceptual framework and hypotheses

1. Proposed conceptual framework

A holistic perspective needs to 1) account carefully for the expanding range of risks; 2) involve with all relevant stakeholders affected by agricultural risks in the supply chain and take action to manage them; 3) analyze the different risk management strategies; and 4) understand the diversified steps in the process of risk management (World Bank, 2016).

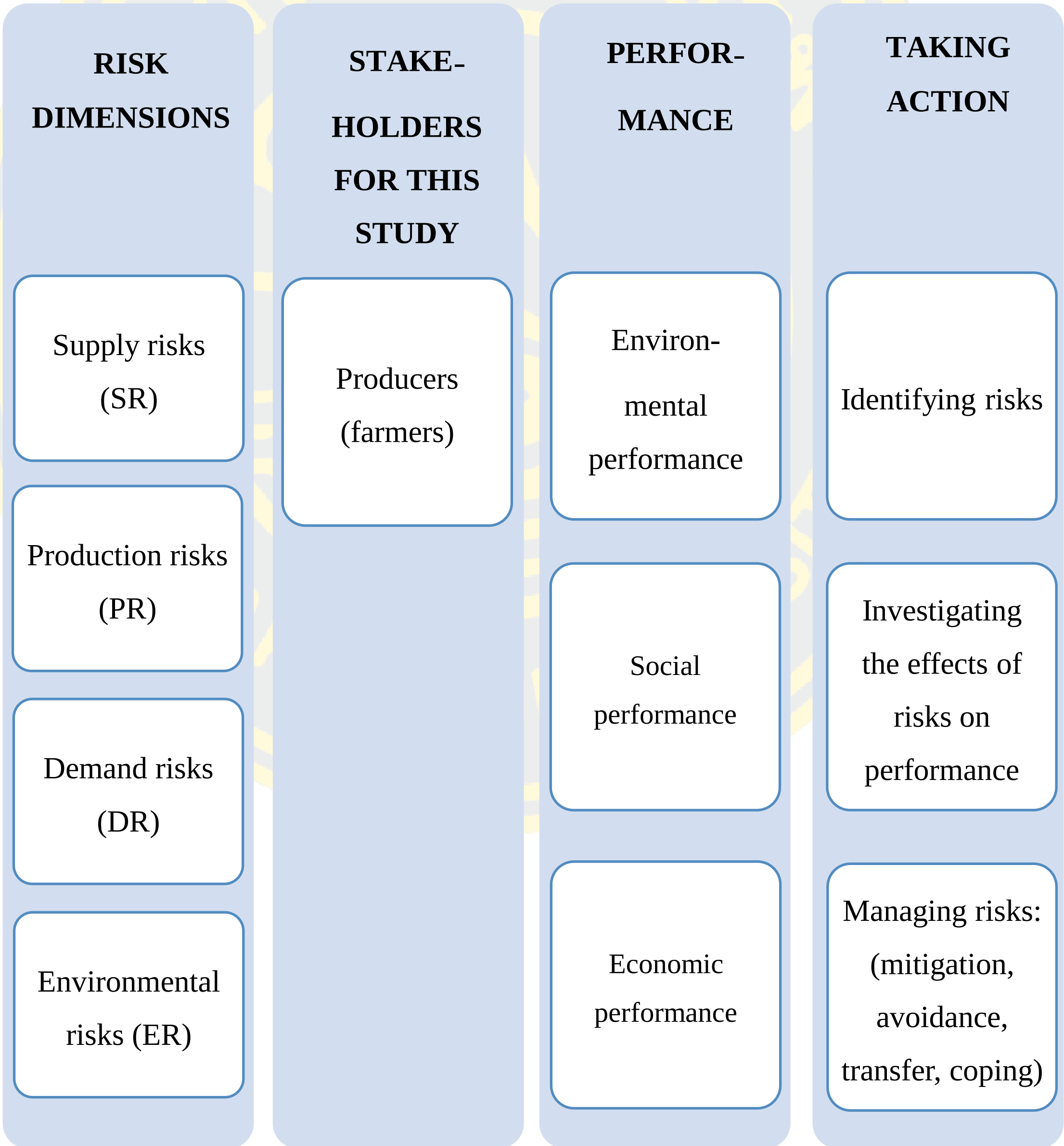


Figure 1 Core risk management in rice supply chain

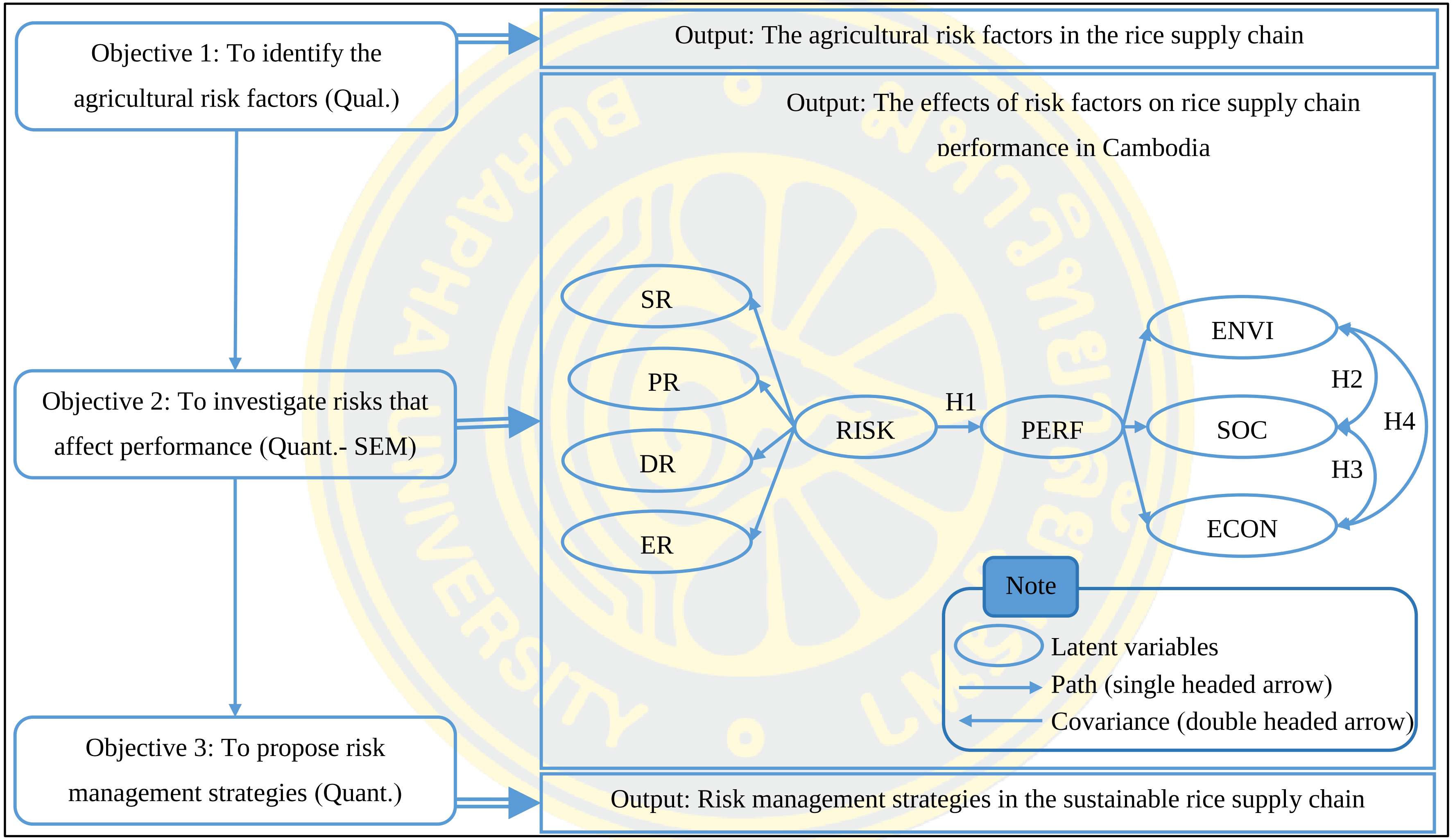


Figure 2 The proposed conceptual framework for this research (Mixed method)

The primary objective of this conceptual framework is to analyze the risks in the rice supply chain in Cambodia (Figure 1 and 2). It also focuses on three specific tasks: identification, investigation, and management. A mixed-methods approach is crucial in this conceptual framework. It is a methodology whereby the scientific researchers collect data, analyze data, and interpret results by integrating qualitative data and quantitative data in unique research to answer their research questions or hypotheses (Creswell & Creswell, 2018). This conceptual framework relies on academics in the wide range of fields between integrated theory and practice in the supply chain.

The first step of this process is risk identification and risk prioritization to 1) gather the secondary data for a desk-level analysis and collect preliminary data (open-ended survey) to confirm factors; and 2) conduct an in-depth interview with relevant experts to prioritize the risk factors. This new conceptual framework builds on the four clusters of risk factors as previously illustrated in the literature. Risks, which agricultural stakeholders face, can be organized into four classifications: supply risks (SR), production risks (PR), demand risks (DR), and environmental risks (ER). The three primary attributes of agricultural risks are losses, uncertainty, and hazard. Agricultural risk is a combination of the severity of the effects and the possibility of the occurrence (World Bank, 2016). The risk prioritization matrix (e.g., Thun & Hoenig, 2011) helps classify risks in terms of likelihood and severity of effects.

The structural equation model, known as causal modeling or analysis of covariance structures, is used in the second objective. SEM is a statistical tool to analyze the relationship between latent variables. Latent variables refer to latent factors that cannot be observed directly by researchers. Observed variables estimated latent variables. Observed variables (manifest variables) are measured directly by the researchers (Jason & Glenwick, 2016). SEM is represented as

$$\eta = \alpha + B\eta + \Gamma\xi + \zeta \quad (1)$$

where $\eta = (\eta_1, \eta_2, \ldots, \eta_m)$ and $\xi = (\xi_1, \xi_2, \ldots, \xi_n)$ are random vectors of endogenous unob-served variables and exogenous un-observed variables, respectively. Alpha (α) is a vector of intercept terms; B and Γ are regression coefficient matrices; $\zeta = (\zeta_1, \zeta_2, \ldots, \zeta_m)$ is a random vector of latent error variables. Vectors η and ξ cannot be observed directly; however, vectors $y = (y_1, y_2, \ldots, y_p)$ and $x = (x_1, x_2, \ldots, x_q)$ are observed, such that the measurement equations are given by

$$y = \tau_y + \Lambda_y + \eta + \varepsilon \quad (2)$$

$$x = \tau_x + \Lambda_x + \xi + \delta \quad (3)$$

where y and x are vectors of observed variables; τ_y and τ_x are vectors of intercept terms; Λ_y and Λ_y are regression coefficient matrices; η and ξ are latent var-iables; ε and δ are vectors of errors terms in the respective equations (Jöreskog et al., 2016). Moreover, this conceptual framework relies on the structural equation model (SEM) for investigating risks that affect rice supply chain performance (environmental, social, and economic aspects).

The end output of this conceptual framework is to propose appropriate solutions to mitigate, avoid, transfer, and cope with agricultural risks. Risk mitigation (ex-ante risk management strategy) is a plan to lessen the likelihood of occurrence or reduce the impact of the risks; risk avoidance (ex-ante risk management strategy) occurs when there are high risks (APICS, 2017). Moreover, risk transfer, an ex-ante risk management strategy, occurs when stakeholders can transfer risks from one party to another party or process (for example, agricultural insurance) (Alam et al., 2020; APICS, 2017; Soullier & Moustier, 2018; Usami, 2019). Additionally, an ex-post risk management strategy (risk coping) is needed to help stakeholders better absorb and rescue from the effects. Risk coping strategies include donations (in-kind or cash), likelihood recovery programs, etc. The quick interventions often reduce loss and are financially beneficial (World Bank, 2016).

2. Hypotheses

H1: Rice supply chain performance is significantly affected by the rice supply chain risks.

H2: There is a relationship between environmental performance and social performance.

H3: There is a relationship between social performance and economic performance.

H4: There is a relationship between environmental performance and economic performance.

Contribution of research

The result of this scientific research can be useful for:

1. Farmer community

It is particularly useful for farmers to know the problems, the advantages of risk management, and the effective utilization of this academic study into practical activities.

2. Commercial institutions

Even though this study focuses on farmers, it also can provide a valuable document for the commercial sector. Risks can also extend over the inbound stage and the outbound stage. Thus, they can impact farmers and the multiple stakeholders in the supply chain. When commercial players coordinate sufficiently, they help farmers and protect their interests sustainably.

3. Government

This survey can provide a helpful document for the government, a significant player, making policies, preparing plans, and developing strategies.

4. Non-profit organizations

It is significant for NGOs to know the situation of the supply chain. Then, they can provide training, especially to create development programs or projects to find optimal ways to improve the current problems related to the supply chain.

5. Academics

This scientific research can contribute to academics in various fields between integrated theory and real practice in the supply chain.

Scope and limitations of the research

1. Scope of the research

1.1 The duration of the study is three years, and it is conducted only on the rice supply chain in one province of Cambodia, namely, Battambang Province a potential rice producer.

1.2 The population for quantitative methodology and qualitative methodology in this scientific research are farmers who are producing rice in Cambodia and experts. Also, the respondents will be restricted in size to those who have already availed of the supply chain, as the research title suggests.

1.3 The primary objective of this research attempts to analyze the risks in the rice supply chain in Cambodia. The study focuses on three specific objectives such as 1) Identifying the agricultural risk factors in the rice supply chain, 2) Investigating risk factors that affect to rice supply chain performance, and 3) Proposing risk management strategies in the sustainable rice supply chain management. Any other concerns or issues that may arise but are not part of the objectives are hereby recommended for separate research or study in the future.

1.4 Two main variables for this scientific study include latent and observed variables. Latent variables refer to latent factors that the researcher cannot observe directly, including 1) risk, 2) supply risks, 3) production risks, 4) demand risks, 5) environmental risks, 6) performance, 7) environmental performance, 8) economic performance, and 9) social performance. Observed variables, or manifest variables, are measured directly by the researcher, encompassing indicators in each individual.

2. Limitations of the research

2.1 The sensitive raw data is prohibited by the researcher to avoid obtaining biased data from the samples.

2.2 The study is mainly based on questionnaires. The assumption is constructed that there are no errors in translation from English to Khmer for the research questionnaire.

Terms definition

1. Risk: Risk is a combination of the associated probability of occurrence (the chance, likelihood, or frequency of something happening) and the impact (outcome) of an event (American National Standards Institute, 2011, as cited in Luko, 2013). The three primary attributes of agricultural risks are losses, uncertainty, and hazard (World Bank, 2016).

2. Risk management task: It includes identifying, investigating effects on performance, and managing risks.

3. Sustainable performance: Sustainable performance refers to the consideration of the dimension of environmental performance, the dimension of social performance, and the dimension of economic performance.

4. Supply chain management: The definition is as follows: SCM includes the planning and managing of all activities associated with all logistics management activities, sourcing and procurement, and conversion. In essence, it also includes coordination and collaboration with channel partners such as suppliers, intermediaries, third-party service providers, and buyers. Importantly, SCM integrates supply and demand management from upper stream to lower stream (Golinska, 2014).

5. Risk management: According to ISO, risk management (RM) is the coordinated action to direct and control an organization concerning risk (American National Standards Institute, 2011, as cited in Luko, 2013).
Risk management strategies include ex-ante risk management strategies (risk mitigation, risk avoidance, risk transfer) and ex-post risk management strategies (risk coping) (APICS, 2017; World Bank, 2016).

6. Supply chain risk management (SCRM): According to Blos (2009) as cited in de Oliveira et al. (2017), SCRM is the intersection between supply chain management (SCM) and risk management.

7. Risks of rice supply chain: They comprise supply risks, production risks, demand risks, and environment risks.

CHAPTER 2
LITERATURE REVIEW

This chapter aims to review the risk analysis of the rice supply chain in relevant literature to identify significant findings and reveal research gaps under risk factors (internal and external supply chain risks), sustainable performance factors, the effects, risk management strategies, and research methods. This review determines the most suitable approach to analyzing risks in supply chains from a decade of lessons learned across nations, especially Cambodia. Likewise, lessons learned from government agencies, international agencies, universities or institutions, and NGOs are valuable, and the electronic academic databases index an ample body of related documents and data via platforms like ScienceDirect, ProQuest, Google Scholar, EBSCOhost, Taylor & Francis, Emerald Insight, and other. Even though this literature review is related to developing and developed countries, most literature concentrates on developing countries because they are associated with Cambodia, the least developed country (LDC). On the other hand, a few academic papers are relevant to this study (case study in Cambodia); this review cannot go in-depth insights into Cambodia.

This chapter consists of four primary phases as the following:

1. Rice supply chain in Cambodia: concentrating on the overview of the Cambodian rice supply chain, the successes, opportunities, risks, and challenges of Cambodia's rice supply chain;

2. Supply chain risk management (SCRM): illustrating the overview of SCRM; identifying risk factors and priorities in ASC; demonstrating the sustainable performance by covering three dimensions (3D)-environmental, social, and economic performance in ASC; proposing risk management strategies in the sustainable rice supply chain management; highlighting a potential research gap from previous studies and adopting for this research.

3. Structural equation modeling and method application: modeling approaches for ASCM and research methods from previous studies;

4. Conclusion for the chapter.

Rice supply chain in Cambodia

1. Overview of Cambodia rice sector

Over the last 20 years, Cambodia has achieved noticeable economic development in Southeast Asia, with a predicted GDP growth of 6.8 percent in 2020 (Table 1). While Viet Nam (6.7 percent), Thailand (3.2 percent), and Singapore (1.4 percent), it means that Cambodia is recognized as a better performer than other countries in the region. The RCG succeeded in attaining status as a middle-income country (MIC) in July 2016, and it alleviated the poverty rate from 47.8 percent (2007) to 13.5 percent (2014) (Fung & McAuley, 2020). The economy's growth rate is also more than 5.0 percent every year since 1998. Moreover, the total GDP in 2017 was USD 22.2 billion (Limited et al., 2020).

Table 1 GDP Growth rate (percent per year)

Name	2018	2019		2020	
		ADO 2019	Update	ADO 2019	Update
SEA	**5.1**	**4.9**	**4.5**	**5.0**	**4.7**
BN	0.1	1.0	1.0	1.5	1.5
CM	7.5	7.0	7.0	6.8	6.8
ID	5.2	5.2	5.1	5.3	5.2
LA	6.3	6.5	6.2	6.5	6.2
MY	4.7	4.5	4.5	4.7	4.7
MM	6.8	6.6	6.6	6.8	6.8
PH	6.2	6.4	6.0	6.4	6.2
SG	3.1	2.6	0.7	2.6	1.4
TH	4.1	3.9	3.0	3.7	3.2
VT	7.1	6.8	6.8	6.7	6.7

Note: GDP = Gross Domestic Product; ADO = Asian Development Outlook;
SEA = Southeast Asia; BN = Brunei Darussalam; CM = Cambodia;
ID = Indonesia; LA = Lao; MY = Malaysia; MM = Myanmar;
PH = Philippines; SG = Singapore; TH = Thailand; VT = Viet Nam
(Fung & McAuley, 2020)

Cambodia faces more challenges from many factors, including the negative aspect of certain risks (such as Covid-19, a worldwide economic slowdown, and the loss of EBA-trade preferences) and long-term challenges (such as climate issues, technological problems, and unknown-unknown (Asian Development Bank, 2020). According to the Global Competitiveness Index (GCI), in 2017-2018, the kingdom was ranked 94th out of 137 countries, thus highlighting Cambodia's slow increase in competitiveness (Figure 3) (Schwab, 2017). Although the World Bank now classifies Cambodia as a lower-middle-income country, the kingdom remains one of the least developed countries in the world (LDC) according to the United Nations (UN). The kingdom aims to become eligible for LDC graduation by 2024 (World Bank, 2017). In addition, GPD per capita in 2017 was only USD 1,384.42, which is still low when compared to global standards (Fung & McAuley, 2020).

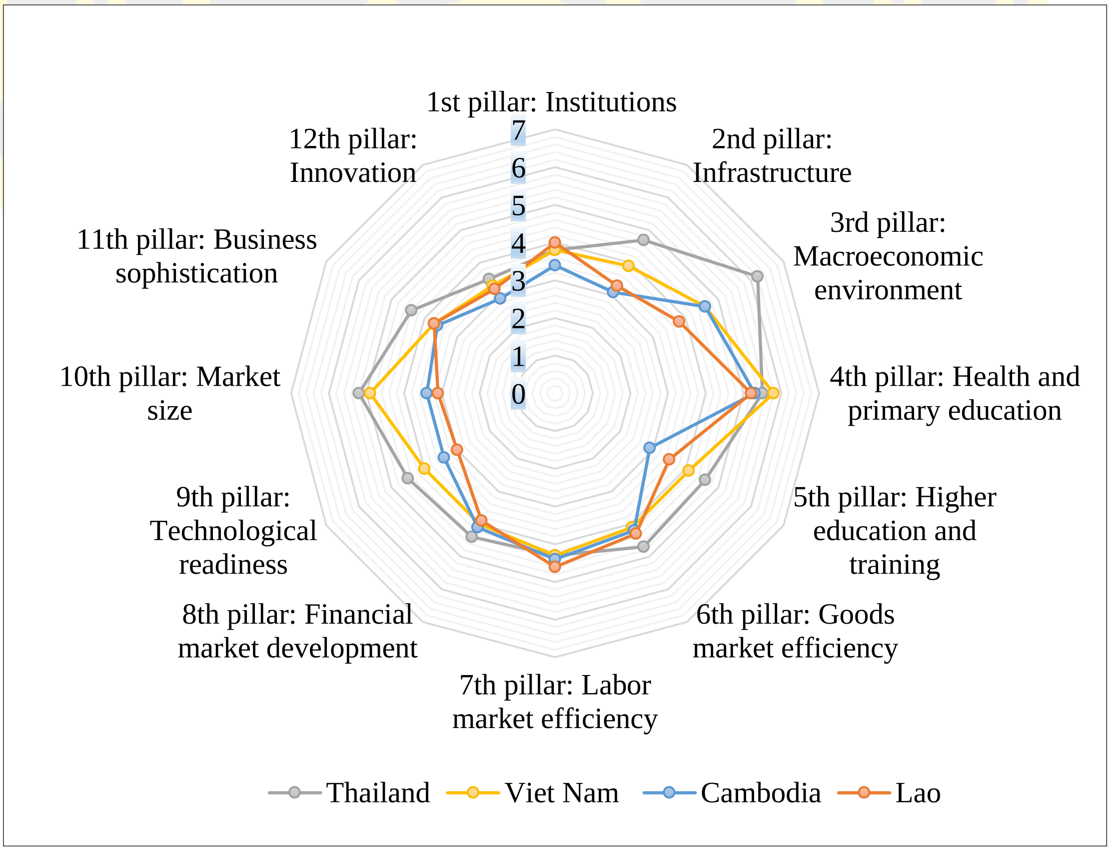


Figure 3 Cambodia continue to lag competitiveness measurement in abroad

Sources: Authors' own making by using data from Schwab (2017)

Agriculture water management, especially irrigation, is encouraged Royal Government of Cambodia (RGC) to alleviate poverty and develop the country's economy. However, Cambodia's irrigation systems are still limited, and irrigated areas are still low. Irrigation plays a crucial role in Cambodia's rice production for commercialized farming, and it is also a significant part of securing crop diversification in both wet and dry seasons (BDLINK, 2017). As stated by Cambodia Information System On Irrigation Schemes (CUSIS), irrigated schemes in Cambodia are currently more than 2,300 schemes covering almost one million hectares in the wet season and half this area in the dry season such as nearly half of these schemes (~900) are degraded, one quarter (~600) is partially working, one fifth (~450) are highly degraded, and other schemes (~350) are good condition (Figure 4) (Venot & Fontenelle, 2016). Sithirith (2017) demonstrated that Cambodia faces water resources challenges and constraints- a scarcity of water resources in the dry season and abundant water in the wet season.

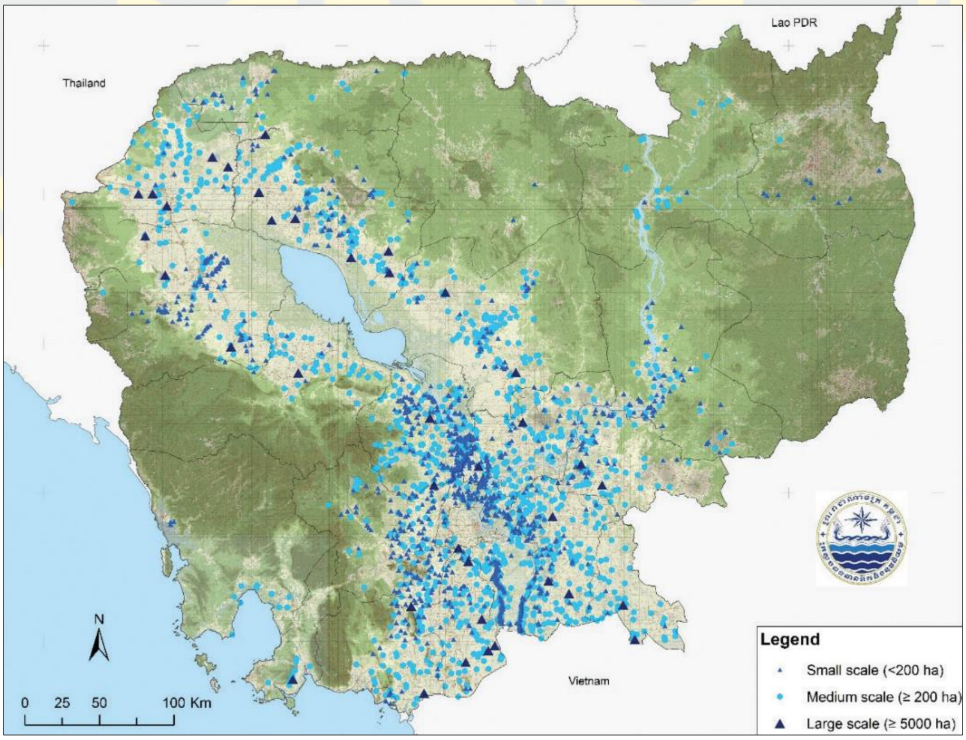
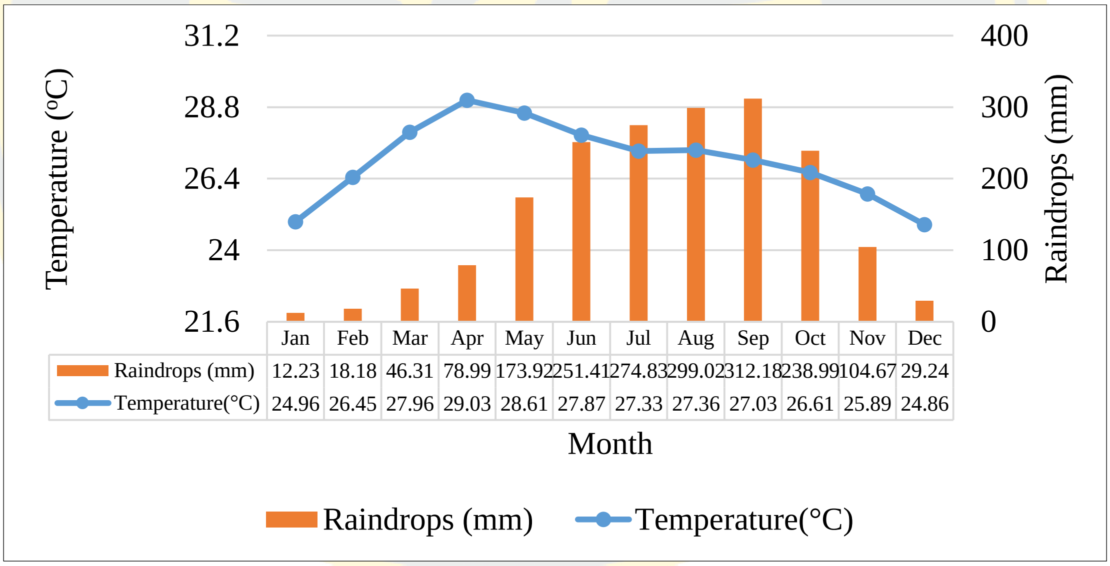


Figure 4 Cambodia irrigated schemes by geographic distribution
Sources: Venot and Fontenelle (2016)

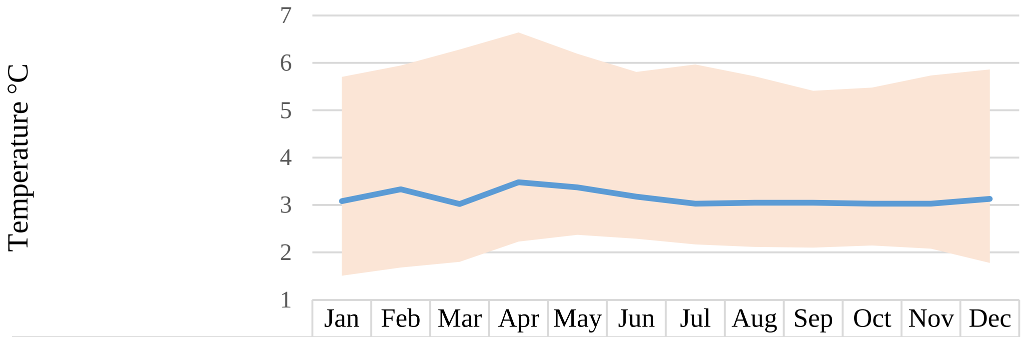
Cambodia is one of the most threatened countries in Southeast Asia, affected by floods, droughts, typhoons, and climate change (Davies et al., 2015). As a least developed country, Cambodia is highly vulnerable to climate change because of geography, agricultural dependence, poor adaptive ability, insufficient financial resources, and limited human resources. The most vulnerable sectors to climate fluctuation impacts are agriculture, infrastructure, forestry, coastal areas, and people's health. For the agricultural sector, most agricultural production relies on raindrops or water resources from the Tonle Sap Great Lake. It is absolutely sensitive when extreme changes in local climate and monsoon regimes occur (UNFCCC, 2017). Figure 5 shows the monthly rainfall and temperature on average from 1901 to 2016, and Figure 6 shows the predicted fluctuation of monthly temperature from 2080 to 2099.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Raindrops (mm)	12.23	18.18	46.31	78.99	173.92	251.41	274.83	299.02	312.18	238.99	104.67	29.24
Temperature(°C)	24.96	26.45	27.96	29.03	28.61	27.87	27.33	27.36	27.03	26.61	25.89	24.86

Figure 5 Monthly rainfall and temperature on average from 1901 to 2016

Sources: World Bank Group (2020)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Top °C	5.59	5.68	5.97	5.88	5.09	4.69	5.06	4.8	4.41	4.44	4.87	5.44
Bottom °C	1.68	1.91	2.07	2.64	2.83	2.72	2.56	2.49	2.47	2.53	2.44	2.04
Ensemble Median °C	3.08	3.33	3.02	3.48	3.37	3.18	3.03	3.05	3.05	3.03	3.03	3.13

Range and Ensemble Median

Figure 6 Predicted fluctuation of monthly temperature from 2080 to 2099

Sources: World Bank Group (2020)

Cambodian farming area consisted of 4.5 million hectares in 2013 out of total land (181,035 km^2). The primary crop is paddy rice with 68 percent of cultivated areas, followed by industrial crops (21 percent), rubber crops (7 percent), and other permanent planation (4 percent). Geographical zones in Cambodia are classified into five primary zones: the Tonle Sap areas (farming land at 42 percent), the Central plain (farming land at 32 percent), Phnom Penh (farming land at 1 percent), coastal zone, and mountainous zone or plateau zone (BDLINK, 2017). As in the Rectangular Strategy, Cambodia set out the program such as 1) reinforcing the land management system, 2) facilitating land allocation and usage, 3) making sure the safety of land titles for owners, 4) terminating illegal land grabbing and anarchic, and 5) and protecting the abuse of land possession and holding concession lands for speculative intended or unproductive intended (Fung & McAuley, 2020). However, about 1.8 million households (five members per household on average) produce rice. Most of them are subsistence because they own agricultural land of less than one hectare, as stated in Cambodia Agricultural Census (2013) as cited in Goletti and Sovith (2016).

Agriculture plays a crucial role in Cambodia's economy and helps many vulnerable people out of poverty (Heylen et al., 2020), accounting for 30.5 percent of GDP in 2014 (Limited et al., 2020); namely, 1) supplying food for new population growth, 2) providing sufficient raw materials for the growth of the industrial sector, 3) giving primary sources of employment for the workforce, 4) generating profit from foreign exchange, and 5) providing of a market for goods and services among other sectors (Suy et al., 2018). Cambodia's rice accounts for 50 percent of the agriculture sector's output, 75 percent of rice farming is produced in the primary wet season under rain-fed agricultural systems, and more than 80 percent of the cropping area (Beecher et al., 2014). Farming growth is a primary source of poverty alleviation. For instance, the poverty rate went down dramatically from over 60 percent in 2000 to 13.5 percent in 2014 (Figure 7) (OECD, 2017).

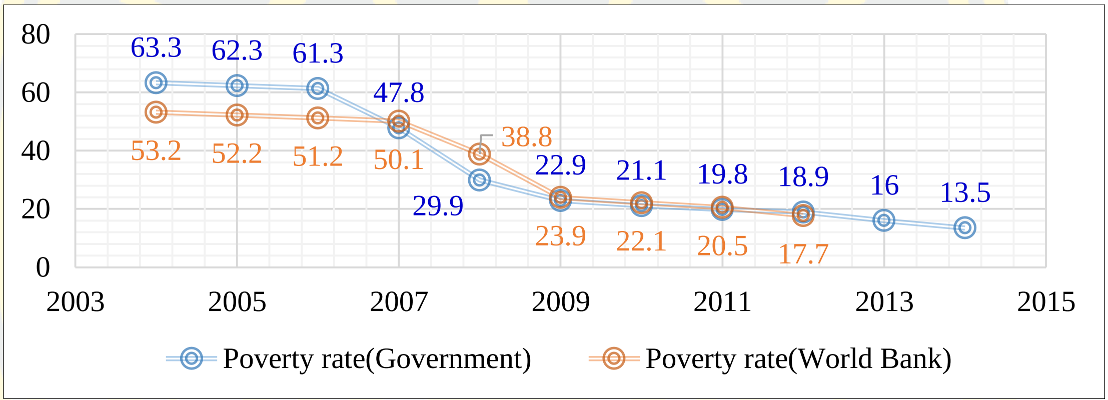


Figure 7 Poverty rate declined dramatically in the past decade

Sources: OECD (2017)

Rice is the mainstay in Cambodia. Approximately 3 million people are employed in the rice sector. Paddy production takes place at 3.6 million hectares and yields around 9.9 million tons. Annual rice production is greater than domestic consumption by around 5 million tons, and this excess is exported to China, EU, and ASEAN countries via informal and formal market channels (Ponleu & Sola, 2018). According to data from one window service for Rice Export formalities (SOW-REF) (n.d.) as cited in Ponleu and Sola (2018), rice exports increased rapidly from 2010 (105,259 metric tons) to 2017 (635,679 metric tons), respectively.

Table 2 shows the goals and indicators of the rice value chain.

Table 2 Goals and indicators of rice value chain

Indicator of rice value chain	Unit	2015	2020	2025	2030
Paddy land	‘000 ha	3,047	3,124	3,124	3,124
Rice yield	kg/ ha	3,037	3,436	3,888	4,398
Rice production	000 ton	9,255	10,735	12,146	13,742
Farm-gate price	$/ kg	0.250	0.25	0.25	0.25
Production value	$ million	2,314	2,684	3,036	3,435
Domestic consumption amount	000 ton	3,231	3,532	3,824	4,099
Amount for feed, seed, and feed	1 ton	1,203	1,180.86	1,214.57	1,236.76
Amount of rice export	000 ton	500	1,144	2,301	3,705
Production process in CM	percent	43	49	61	71
Production process out CM	000 ton	5,255	5,443	4,782	3,942
Domestic price	$/ kg	0.7	0.75	0.81	0.88
Export price	$/ kg	0.7	0.75	0.81	0.88
Export value	$ million	350	863	1,869	3,243
VA in processing & EXP.	$ million	820	1,271	2,047	3,125
Total value*	$ million	3,134	3,955	5,084	6,560
Total value per hectare	$/ ha	1028	1266	1627	2100
No. of labor in production	no.	609	625	625	625
No. of labor in post-production	no.	40	53	74	98
Wage** in production	$/ day	8	9	10	11
Wage** in post-production	$/ day	16.40	19.21	22.24	25.51
Farmer’s income/ Hectare	$/ ha	380	430	486	550

Note: CM = Cambodia; VA = Value Added; EXP = Export; NO = Number (s); HA = Hectare; Kg = Kilogram; $ = USD. *Total Value includes processing, production, and marketing; **Wage=Return to labor (Goletti & Sovith, 2016)

2. Rice supply chain structure in Cambodia

The multiple stakeholders in the rice supply chain include farmers, millers, wholesalers, retailers, exporters, government, and support services providers by interacting with each other (Linn & Maenhout, 2019; Muthayya et al., 2014;

Rohmah et al., 2015). Figure 41 shows the concept of the rice supply chain in Cambodia.

Cambodian farmers grow rice during two seasons, namely the wet season and the dry season. Sowing begins in May during the wet season, and then the crop is harvested between the middle of November and the end of January in the coming year. For the dry season, sowing starts in November, and then it is harvested between March and May in the coming year (Ward et al., 2016).

Some of the primary indicators of the 2030 vision contain the enormous rise in the export value from $350 million in 2015 to $3,243 million in 2030; the increasing more than 70 percent of production processed in Cambodia from 43 percent; above $3.1 billion of value-added in the industry; generating the agricultural income from $380/ ha in 2015 to USD 550/ ha in 2030 by increasing 45 percent (Goletti & Sovith, 2016). Cambodia moves from rice paddy to rice exporters by adapting contemporary milling ability involving quality and volume management. Cambodia launched milled rice standards in terms of fragrant and white in 2013. These quality assurances are recognized internationally and confident by international consumers. The impressive success, Cambodia won the "World's Best Rice" award for three years in a row at World Rice Conference. With a ten-fold rise in just three years, Cambodia exported rice increasingly from 40,000 metric tons in 2010 to almost 400,000 metric tons in 2013 to 66 countries (IFC, 2015). As stated in the report, Cambodia exported 514,149 tons of rice to 55 countries and other regions from January to November 2019, up 3.4 percent by comparing the same period in 2018-especially China (205,358 tons of milled rice). China is still the top purchaser from Cambodia from January to November 2019, as demonstrated by the Secretariat of One Window Service for Rice Export (n.d.) as cited in Xinhua (2019). Figure 8 shows the top twenty rice exporters and importers of the world in 2016.

Rank	Export			Import	
	Name	**QTY (tons)**	**%**	**Name**	**QTY (tons)**
01	Thailand	9,870,079	25.65%	China	3,522,879
02	India	9,869,281	25.64%	Benin	1,463,555
03	Viet Nam	5,210,843	13.54%	Côte d'Ivoire	1,283,273
04	Pakistan	3,947,365	10.26%	Indonesia	1,282,427
05	USA	3,315,836	8.62%	Saudi Arabia	1,235,715
06	Uruguay	899,523	2.34%	UAE	1,208,582
07	Italy	651,443	1.69%	Iran	1,057,984
08	Brazil	630,328	1.64%	Senegal	973,745
09	Paraguay	554,121	1.44%	South Africa	958,165
10	Cambodia	529,888	1.38%	Iraq	923,544
11	Argentina	527,309	1.37%	Malaysia	821,869
12	China	459,749	1.19%	USA	748,559
13	UAE	458,077	1.19%	Brazil	713,108
14	Myanmar	280,662	0.73%	Ghana	698,396
15	Spain	269,286	0.70%	Japan	685,757
16	Belgium	262,141	0.68%	Mexico	671,532
17	Niger	223,092	0.58%	Cuba	659,930
18	Russian	190,127	0.49%	Guinea	654,477
19	Netherlands	168,897	0.44%	Cameroon	615,128
20	Australia	166,907	0.43%	Kenya	609,804

Figure 8 Top twenty rice exporters and importers of the world in 2016

Sources: FAOSTAT (2018) as cited in Kea et al. (2019)

2.1 Farmers

According to the table below (Table 3), about 59 percent of all households have farmland less than 1ha, followed by 35 percent of all households having farmland from 1ha to 3 ha. In Phnom Penh, Cambodia's capital, households own less than one hectare with 91.7 percent is the highest by comparing in the four zones- plain zone, Tonle Sap zone, coastal zone, and plateau zone or mountain zone (National Institute of Statistics-Ministry of Planning, 2018a).

Table 3 Cambodian farmland by size and zone in 2017

Farmland (ha)	**Cambodia**	**Phnom Penh**	**Plain**	**Tonle Sap**	**Coast**	**Plateau/ Mountain**
			Number of households (#)			
<1	1,976	25	1,074	451	197	228
1-1.9999	901	2	287	387	48	177
2-2.9999	265	0	69	101	10	85
3-3.9999	77	1	12	29	2	33
4-4.9999	45	0	11	24	0	11
5-5.9999	56	0	10	30	1	15
10-& >	17	0	3	10	0	3
Total	**3,336**	**28**	**1,466**	**1,032**	**259**	**551**
			Percentage of households (percent)			
<1	59.2	91.7	73.3	43.7	76.0	41.4
1 -1.9999	27.0	6.5	19.6	37.5	18.7	32.1
2-2.9999	7.9	0	4.7	9.8	3.9	15.3
3-3.9999	2.3	1.8	0.8	2.8	0.8	6.0
4-4.9999	1.4	0	0.8	2.3	0	1.9
5-5.9999	1.7	0	0.7	2.9	0.6	2.7
10-& >	0.5	0	0.2	1.0	0	0.5
Total	**100**	**100**	**100**	**100**	**100**	**100**

Sources: National Institute of Statistics-Ministry of Planning (2018a)

Figure 9 demonstrates that rice is one of Cambodian society's most critical agro-food products. The average rice yield in Cambodia is 3.57 t/ ha, and the total production is 10,647,212 tons, with the total area harvested reaching 2,981,680 ha in 2018 (FAOSTAT, 2020).

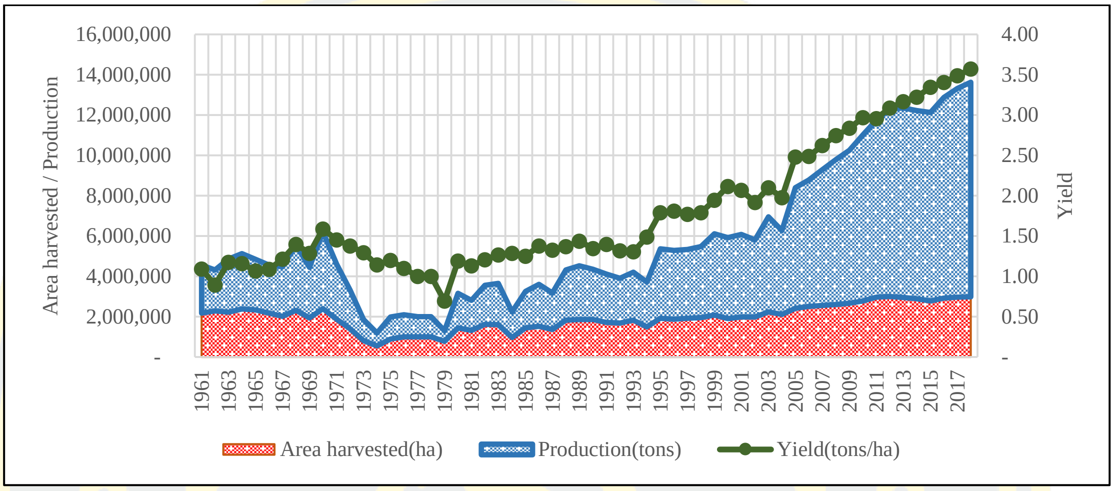


Figure 9 Area harvested, productions, and yield of rice

Sources: Authors' own making by using data from FAOSTAT (2020)

2.2 Millers, exporters, and other traders

Rice is not only significant for agricultural export but also a historic crop of cultural significance. According to the recent changes in public policy from the Royal Government of Cambodia (RGC), Cambodian rice markets have transformed significantly such as managing and developing the industry in terms of enhanced strategic, coordination, and export-focused approach; improving, modernizing millers' capacity in Cambodia; getting the opportunity of export market share in the interest of preferential tariff benefits; and, opening the door for entering the markets (Royal Government of Cambodia, 2014a). For example, RGC approved on policy paper involving the promotion of rice export and rice production on July 25, 2010, by increasing productivity per hectare, making better for international standard of rice mills, and finding global markets for Cambodia milled rice. Besides, the European Union made a significant decision in December 2009 under the system of preferential duties, Everything But Arms (EBA), which includes milled rice production for least developed countries with 30 percent to 40 percent of tariff benefits. Moreover, Asia and the EU opened the door for expanding to markets. The largest markets in Asia were China and Malaysia. As well as France, Poland, the Netherlands, Belgium, and the United Kingdom were the top markets in the EU (The World Bank Group, 2018). Table 4 shows the large-scale rice mills in Cambodia by capacity in 2009 and 2016.

Table 4 Large-scale rice mills in Cambodia by capacity in 2009 and 2016

Name of rice mill	Location	Capacity (MT/ HR)	
		2009	**2016**
Existing 2009			
Angkor Rice (AKK)	Near Phnom Penh	10	30
Golden Rice	Near Phnom Penh	20	55
Green Trade	4 of 6 near Phnom Penh	10	
Lor Ngor Peng	Kampong Cham	8	15
Loran Import-Export	Battambang	12.5	30
Men Sarun	Phnom Penh	24	24
Phou Poy Rice Mill	Battambang	9	20
Subtotal		**93.5**	**174**
New mills			
Baitang	Battambang	20	45
BVB	Kampong Thom	30	80
Chhun Thom	Prey Veng	10	
QQ Rice	Pursat	12	
Sour Keang QC Rice	Kampong Cham	12	
Yam Leoung	Battambang	10	
Vinh Cheang	Kampong Cham	12	
Subtotal		**106**	**125**

Table 4 (Continued)

Name of rice mill	Location	Capacity (MT/ HR)	
		2009	**2016**
Rice Polishing			
Baitang	Battambang	30	45
Int'l Rice Trade	Phnom Penh	10	
Khmer Foods	Phnom Penh	10	15
Loran Import-Export	Battambang	30	30
Subtotal		**80**	**90**
Rice Upgrading	Sih' Gile Port		
Ying & Yang Rice		**10**	**10**
Grand total		**289.5**	**399**

Sources: Pech (2013); The World Bank Group, (2018)

More than 800 rice mills operate in the kingdom; 200 of the total rice mills are medium or large-size. The list below demonstrates the 50 companies on the top for export in 2018. The top 25 have a capacity of over 2,000 tons per month; others have an ability from 10,000 tons to 20,000 tons per month. On the other thing, rice mills face primary challenges such as 1) most of them operate with low efficiency, 2) they do not produce their paddy, 3) there are the absences of the contract agreement between millers and farmers, but few mills have, and 4) liquidity issues involve pre-finance inputs for contract farmers (Bastiaan Bijl Consultancy, 2019).

1. Amru Rice (Cambodia) Co.,Ltd
2. Anduriz (Cambodia) Sarl
3. Apsara Rice (Cambodia) Co.,Ltd
4. Baitang (Kampuchea) Plc.
5. Battambang Rice Investment Co.,Ltd
6. Boost Riche (Cambodia) Co.,Ltd
7. Cambodian Diamond Seafood & Agriculture Co., Ltd
8. Cambodian Li Shine International Trade Co.,Ltd

9. Cam-Grain Development Co.,Ltd
10. City Rice Import Export Co.,Ltd
11. Ck Rice Trading Co.,Ltd
12. Commodity In Focus Co.,Ltd
13. Domnak Teuk Rice Co.,Ltd
14. Eang Heang Import Export Co., Ltd
15. Fed Rice Battambang Ltd
16. Golden Daun Keo Rice Mill Co.,Ltd
17. Golden Rice (Cambodia) Co.,Ltd
18. Golden Star Ricce Mill And Import Export Co., Ltd
19. Great Green & Grement Asia Pacific (Cam) Co.,Ltd
20. Green Trade Company
21. Guohong (Cambodia) Industry Co., Ltd
22. Herba (Cambodia) Co.,Ltd
23. Indochina Rice Mill Limited
24. International Rice Trading (Cambodia)
25. Jiaxuan Industry Co.,Ltd
26. Jing Mi Rice Mill Co.,Ltd
27. Kampong Thom Rice Mill Limited
28. Khmer Foods Group Co.,Ltd
29. Khy Thay Corporation Co.,Ltd
30. Lbn Angkor (Kampuchea) Co.,Ltd
31. Lim Kheang Hout Import Export Co.,Ltd
32. Lor Eak Heng Sek Meas Rice Co.,Ltd
33. Mekong Oryza Trading Co.,Ltt
34. Nikoline Investment Co.,Ltd
35. Ou Tong Development (Cambodia) Co., Ltd
36. Overseas Foods Import Export Co., Ltd
37. Pheng Leang Seng Import Export
38. Phou Poy Development Import Export Co.,Ltd
39. Primalis Corporation Ltd.
40. Sary Kunthea

41. Signatures Of Asia Co.,Ltd
42. Sok Keo Import Export Co.,Ltd
43. Soma Trading Company Limited
44. T.M.K Investment Co.,Ltd
45. T.O.T (Trust Our Trade) Co.,Ltd
46. Tech Soon Agro Industry Co.,Ltd
47. Thmor Korl Rice Import Export Co., Ltd
48. Vong Bunheng Import Export Co.,Ltd
49. W.K.R Trading Co.,Ltd
50. White Gold Import Export Co.,Ltd

(Bastiaan Bijl Consultancy, 2019)

As of January 2020, the destinations of the Cambodian rice market are the EU (37 percent), China (33 percent), ASEAN (11 percent), and other destinations (22 percent) in a total of 50,450 tones (including fragrant rice was 46,006 (91 percent) tones and long-grain white rice was 4,444 tones (9 percent). Furthermore, Cambodian rice export to the EU market as of January 2020 decreased by 22 percent (5,269 tones), and it declined by 20 percent (3,664 tones) to China market by comparing the same period in 2019 (Table 5) (Cambodia Rice Federation, 2020).

Table 5 Cambodian rice export as of February 2020 by Metric Tons

Monthly	**2017**	**2018**	**2019**	**2020**
January	48,820	62,623	59,625	50,540
February	60,731	47,809	52,861	86,049
March	57,127	50,683	58,335	---
April	45,716	36,239	42,942	---
May	45,243	42,865	36,409	---
June	30,925	31,318	31,366	---
July	27,000	25,543	26,475	---
August	56,274	44,558	34,032	---

Table 5 (Continued)

Monthly	2017	2018	2019	2020
September	49,776	47,626	56,541	---
October	70,149	45,543	59,354	---
November	70,122	62,433	56,209	---
December	73,442	128,985	105,957	---
Total per year	635,325	626,225	620,106	136,589

Sources: Cambodia Rice Federation (2020)

2.3 Service supporters of rice production

2.3.1 Input suppliers

According to the Ministry of Agriculture, Forestry and Fisheries (MAFF) in Cambodia as cited in Vannak (2020) illustrated that the pesticides and fertilizers were imported a total of 1.2 tons in 2019 (a rise of 9 percent per year), to which fertilizers amounted 1.14 million tons and pesticides amounted 810,000 tons. The same source shows that some raw materials for agricultural production rely on imports, causing higher prices of products. The chemical products mainly include pesticides and fertilizers are consumed in Cambodian agriculture. Cambodia does not have manufacturers for producing pesticides, and the majority of pesticide products are imported officially and unofficially from the bordering countries (Preap & Sareth, 2015). Moreover, Cambodia currently imports chemical fertilizer and organic fertilizer greater than one million tons of both (Khmer Times, 2016). MAFF is responsible for registering, granting the license, inspecting, advising technically, and analyzing for doing the scientific test in National Agricultural Laboratory. In recent years, MAFF has made a strong commitment and order to all units to make substantial efforts in management and quality assurance, such as cross-boundary trade, sale, distribution, and utilization of agrochemicals in Cambodia (Preap & Sareth, 2015).

The quality of rice seeds is significant for achieving potential yield and improving agricultural productivity. The most up-to-date techniques of the seed industry comprise diversified development, quality assurance and processing, seed production, marketing, and the action of overseeing by the government. The final users, farmers, need seeds to yield well, the seed industry has to make better to serve their needs and develop their products (International Bank for Reconstruction and Development, 2015). MAFF's priority is to make sure the standard of seed quality, develop diversified registration policies, prepare declarations on seed trading, ensure the standard label (Sovorn & Pros, 2016). Figure 10 shows the market share of Cambodian rice seed.

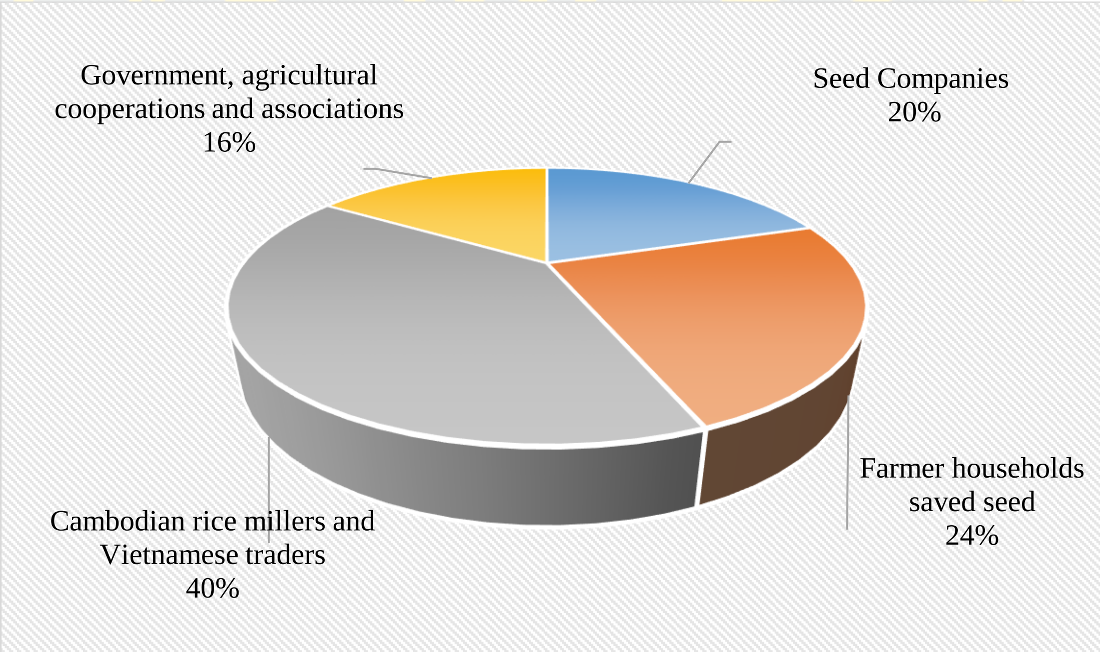


Figure 10 Market share of Cambodian rice seed

Sources: AQIP, n.d., as cited in AGCONASIA, (2017)

2.3.2 Financial institutions

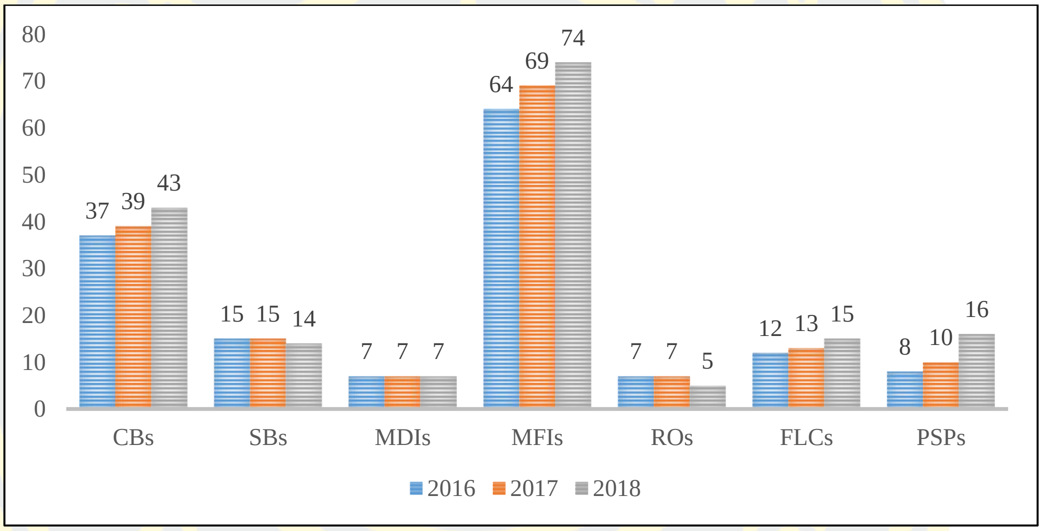
The National Bank of Cambodia demonstrated that in 2018 there are

- 43 commercial banks (13 locally incorporated banks, 13 branches of foreign commercial banks, 17 subsidiary banks)

- 14 specialized banks (1 state-owned; 5 locally incorporated banks; 8 foreign specialized banks)
- 81 micro-finance institutions (7 are deposit-taking institutions)
- 16 payment service providers

(National Bank of Cambodia, 2018).

As of the second quarter in the same year, NBC illustrated that there are 254 credit operators in the countryside, 15 leasing companies (Figure 11) (Pisei, 2020).



Note: Commercial Banks (CBs); Specialized Banks (SBs); Micro-finance Deposit-Taking Institutions (MDIs); Microfinance Institutions (MFIs); Representative Office (ROs); Financial Leasing Companies (FLCs); Payment Service Providers (PSPs)

Figure 11 Cambodian banking population from 2016 to 2018

Sources: National Bank of Cambodia (2018)

Cambodian financial sectors performed well in the previous year but in earlier 2020, facing credit issues. First, drought affects the financial sector. Additionally, microfinance in Cambodia is predicted to slow in 2020 due to external factors-Covid-19 outbreak and partial withdrawal of Every But Arm (EBA) scheme grants (Pisei, 2020).

The banking sector dominates the financial sector in Cambodia. Banks and MFIs in 2015 increased to USD 23.5 billion in total assets and reached USD14.7 billion in total loans (provided USD2.3 billion credit to agriculture) (Bomakara & Helyda, 2016). Additionally, agriculture, manufacturing sector, wholesale, retail, and construction made up almost 75 percent of total domestic credit. Underpinning Cambodia's rice policy in 2010, the growth in the domestic credit sector accelerated from 6.8 percent in 2010 to 11.6 percent in 2015. However, the share of credit in domestic disbursed to the manufactured sector has decreased gradually from 11.5 percent in 2013 to 7.9 percent in 2015 (World Bank Group, 2015). According to NBC (2015) as cited in Bomakara and Helyda (2016) illustrated that banks' loan is allocated to wholesale is 17.01 percent; retail is 15.73 percent; agriculture, forestry, and fisheries is 10.19 percent; other non-financial services is 8.37 percent; manufacturing is 7.61 percent; the mortgage is 7.10 percent; other is 33.99 percent. Figure 12 shows the MFI loan categorized by economic sectors in 2015.

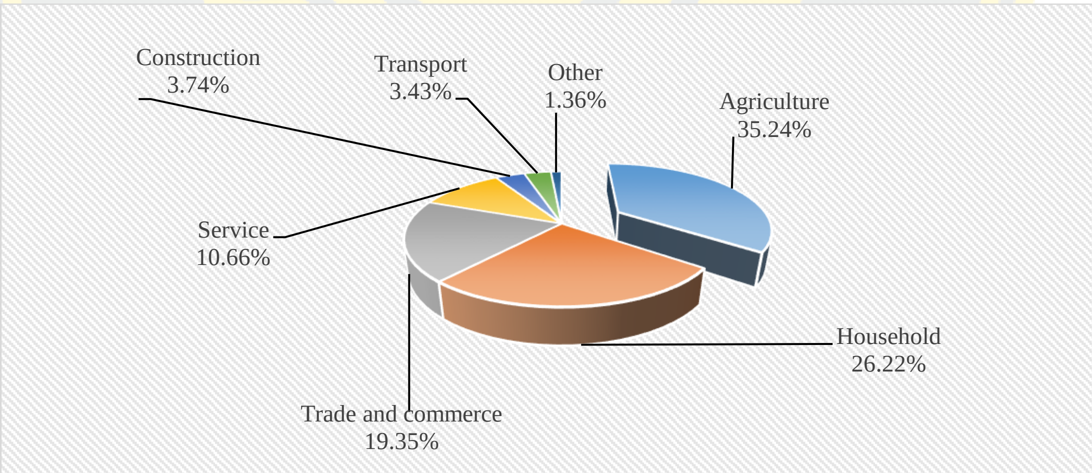


Figure 12 MFI loan categorized by economic sectors in 2015

Sources: Bomakara and Helyda (2016)

Based on a study, approximately 50 percent of agribusiness used financial services from commercial banks. The usage of financial services depends on the agribusiness size-approximately 85 percent were large-scale agribusiness, and 22 percent were macro agribusiness. The same study showed that the majority of rice sellers and input providers are small and micro-sized businesses (covered around 86 percent of rice sellers, around 85 percent of input suppliers); while the minority are large-scale firms (covered 3 percent of rice sellers and 5 percent of input suppliers) (Work Bank, 2013, as cited in Bomakara & Helyda, 2016).

2.3.3 Transportation and logistics

Cambodia at present has four engines of growth: agriculture, tourism, manufacturing, and construction. Effective transport for Cambodia plays an important role in those sectors. For instance, tourism relies on the road and international air transport; the construction subsector and manufacturing subsector depend on water and road transport (e.g., material delivery). Moreover, agriculture is a significant development plan for the Cambodian government; it relies on roads and maritime transport (e.g., product export) (Asian Development Bank, 2019).

ASEAN Highway 1, which links Thailand to Cambodia and Vietnam, has been done. The section of highway from Battambang province to Serei Soaphoan City in Cambodia will be enlarged quickly to be a four-lane road. Additionally, a bridge across the Mekong River to Vietnam has competed. Moreover, road No. 7, as a part of ASEAN Highway 11, has been completed too (Figure 13) (Kerdchuen, 2015).

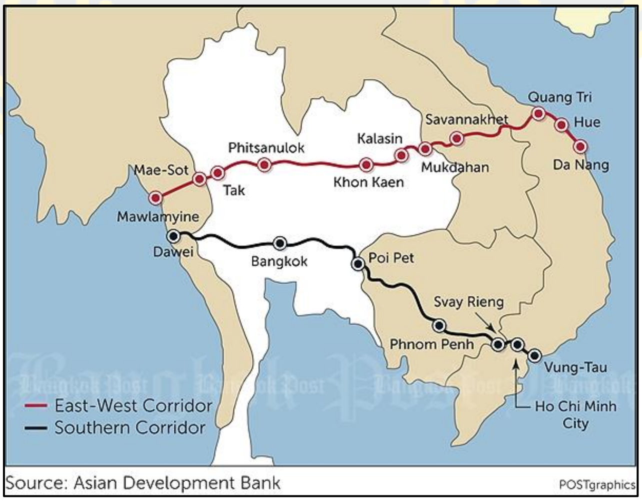


Figure 13 New logistics frontier-Asean highway 1
Sources: ADB, n.d., as cited in Kerdchuen (2015)

The Vietnam Business Forum on the topic of investing in Indonesia and the logistics viewpoint (Table 6) demonstrated the percentage of logistics costs to gross domestic product (GDP) is as follows:

Table 6 Logistics costs to GDP

No	Country	Logistics costs (percent to GPD)	Other
1	Singapore	8 percent	2014
2	Malaysia	13 percent	2014
3	Thailand	15 percent	2013
4	Cambodia	18 percent	A decline from 21 percent previous year
5	Vietnam	20.9 percent-25 percent	2014
6	Indonesia	24 percent	A decline from 26.03 percent in 2013

Sources: Kerdchuen (2015)

Cambodia is located at a strategic site for trading between Thailand and Vietnam. Cambodia's strategic site is helpful for regional logistics, which links ASEAN potential cities (Phnom Penh, Bangkok, and Ho Chi Minh City) and connects two deep seaports, namely Dawei port and Saigon deep seaport and Table 7 shows the logistics-opportunity in Cambodia (KASIKORNBANK, 2018).

Table 7 Logistics-opportunity in Cambodia

	Logistics expertise	Logistics services	Distribution centers and warehouses
Reasons	- Not enough experts in the logistics sector	- Poor infrastructure but noticeable growth in containerized	- Increasing demand for warehouse or distribution centers

Table 7 (Continued)

	Logistics expertise	Logistics services	Distribution centers and warehouses
	- Insufficient training/ instruction in the field of logistics in Cambodia	exports with neighbor countries	
Opportunities	- Provide ability and practical knowledge in logistics management	- Discover and search opportunities to serve logistics services regionally and internationally with efficiency and effectiveness	- Investing money in distribution centers or warehouses (particularly in the primary road between neighbor countries, namely Thailand and Vietnam)

The logistics performance (LPI) (Figure 14) is calculated by the weighted mean of country scores on the six primary dimensions:

1. Customs: the process of clearing with quickness, ease, and other by border control agents;

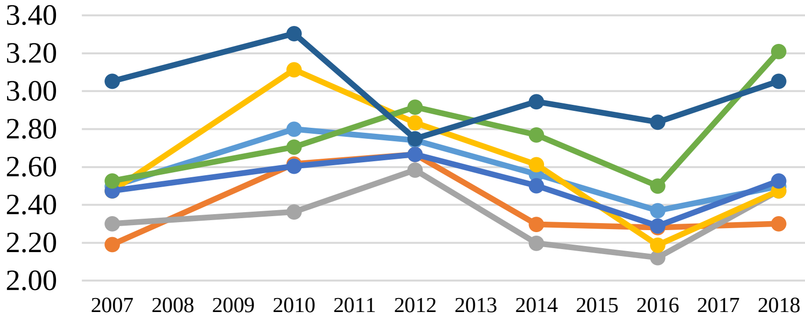
2. Infrastructure: standard of transport and trade (roadways, railways, waterways-ports, information technology-IT, and other);

3. Global shipments: international shipments with the ease of arranging (shipping with competitive prices)

4. Logistics competence: the quality of services involved with customs brokers and transport operators;

5. Capacity to trace and track: the ability of consignment to find and to follow;

6. Timeliness: Shipping to the expected destination on time or on schedule (World Bank, 2018b).



	2007	2010	2012	2014	2016	2018
Overall LPI score	2.50	2.80	2.74	2.56	2.37	2.50
Customs	2.19	2.62	2.67	2.30	2.28	2.30
Infrastructure	2.30	2.36	2.58	2.20	2.12	2.47
International shipments	2.47	3.11	2.83	2.61	2.19	2.47
Logistics competence	2.47	2.60	2.67	2.50	2.29	2.53
Tracking and tracing	2.53	2.70	2.92	2.77	2.50	3.21
Timeliness	3.05	3.30	2.75	2.95	2.84	3.05

Figure 14 Cambodian logistics performance (LPI)

Sources: World Bank (2018b)

Supply chain risk management

Interruptions and ruptures in SC can cause the loss of money and the undermining of reputation. In this respect, there are many researchers interested in SCRM. According to Blos (2009) as cited in de Oliveira et al. (2017), SCRM is the intersection between supply chain management and risk management (Figure 15).

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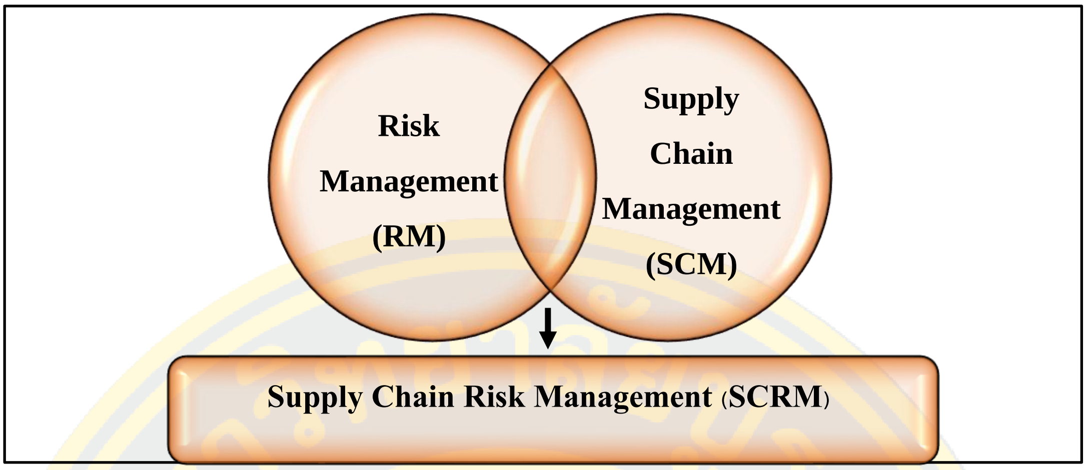


Figure 15 Intersection between ISO 31000:2009 standard and SCM
Sources: Blos (2009) as cited in de Oliveira et al., (2017)

According to ISO, risk management (RM) is the coordinated action to direct and control an organization concerning risk. Risk is a combination of the associated probability of occurrence (the chance, likelihood, or frequency of something happening) and the impact (outcome) of an event (American National Standards Institute, 2011, as cited in Luko, 2013).

The definition is as follows: SCM includes the planning and managing of all activities associated with all logistics management activities, sourcing and procurement, and conversion. In essence, it also includes coordination and collaboration with channel partners such as suppliers, intermediaries, third-party service providers, and buyers. Importantly, SCM integrates supply and demand management from upper stream to lower stream (Golinska, 2014). Figure 17 shows the mapping between the private and public sectors that provide logistical, financial, and technical support services. A basic structure of the agri-food supply chain involves the domestic and international enabling environment. It demonstrates three significant flows: physical product flows, financial flows, and information flows. Additionally, supply chain stakeholders can be inside or outside national borders. Supply chain stakeholders are backward-linked input suppliers (e.g., fertilizer suppliers or seed suppliers), farmers, forward-linked intermediaries, processors, retailers, wholesalers, and exporters (Jaffee et al., 2010). Supply chain management

(SCM) continues advancing and does supply chain professionally for their organizations. For instance, the SCOR Model is the integrated process of enabling spanning between supplier's supplier and customer's customer, plan, source, make, return, and deliver (Figure 16) (APICS, 2017).

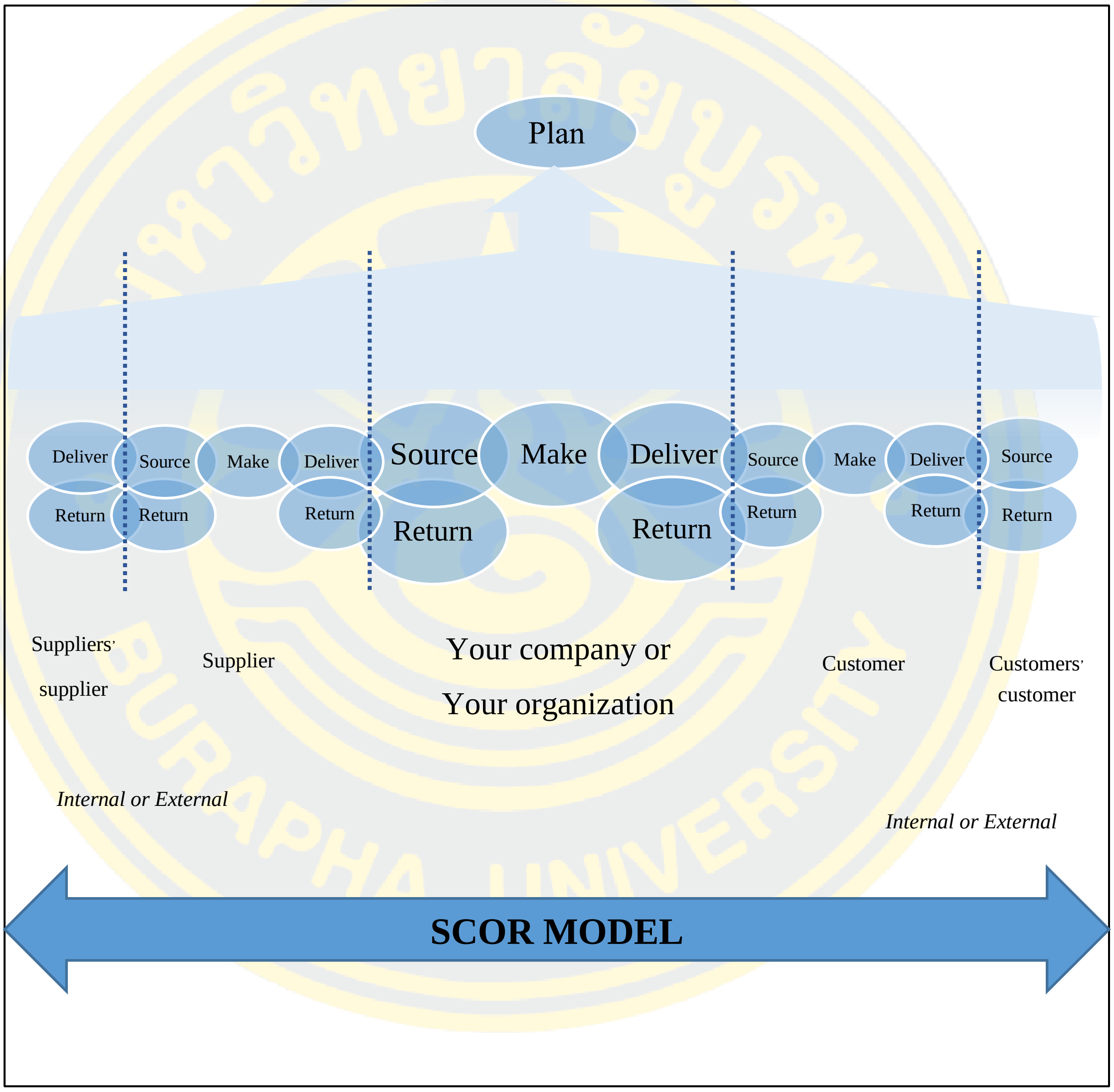


Figure 16 SCOR Model
Sources: APICS (2017)

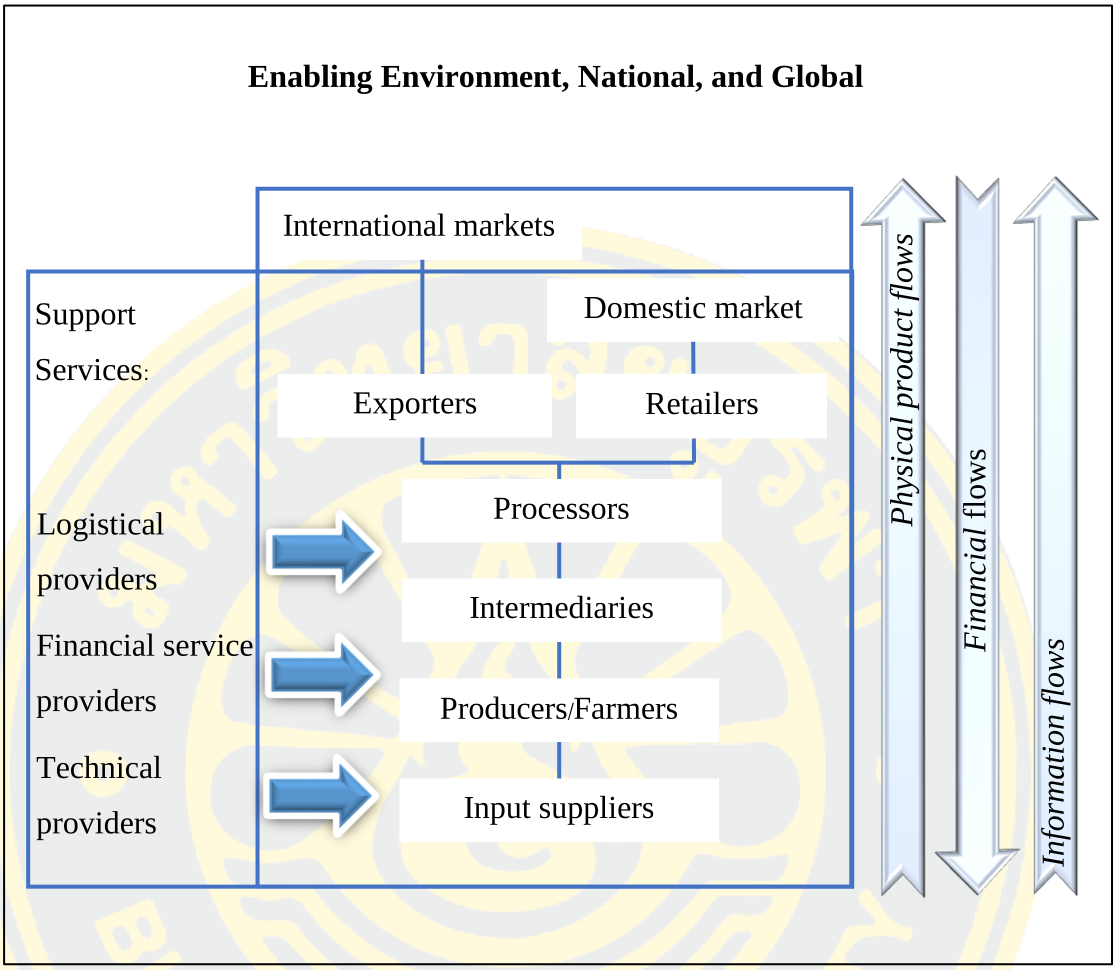


Figure 17 A basic structure of Agri-food supply chain

Sources: Jaffee et al. (2010)

Christopher and Peck (2004) classified risks into three categories: 1) internal to the firm, 2) external to the firm but internal to the supply chain, and, 3) external to the supply chain (Figure 18). The same author sub-divided into five types of risks:

Internal to the firm

- Process risk
- Control risk

External to the firm but internal to the supply chain

- Demand risk
- Supply risk

External to the supply chain

- Environmental risk

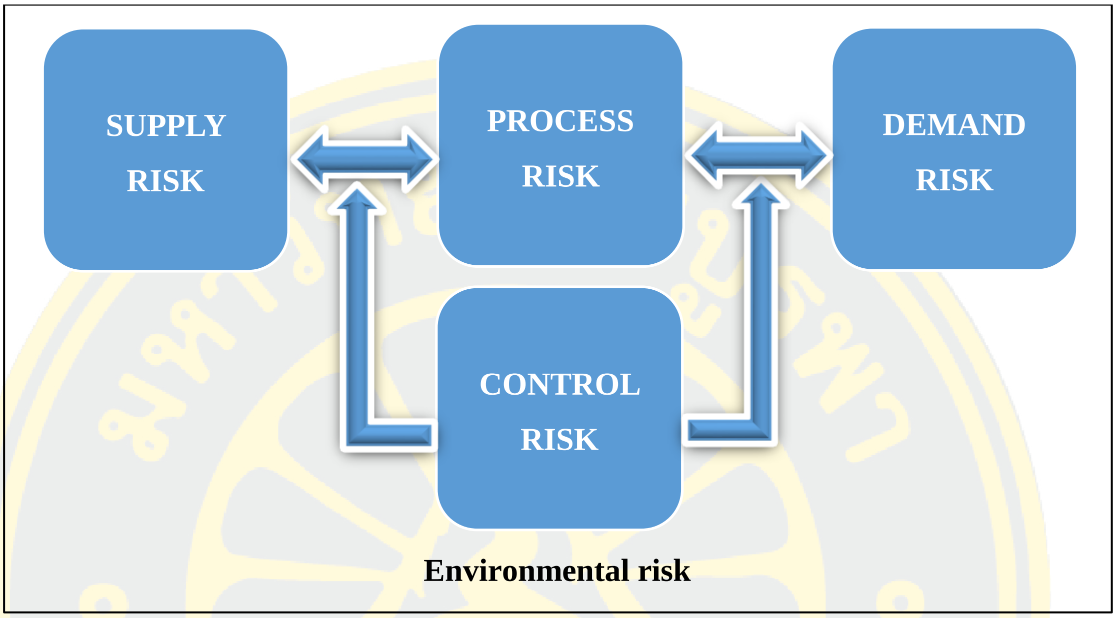


Figure 18 Risk sources in the internal and external supply chain

Sources: Christopher and Peck (2004)

On the other hand, risks are classified primarily into two categories which are internal supply chain risks (ISCR) and external supply chain risks (ESCR) (Kleindorfer & Saad, 2005; Shahbazi et al., 2013; Sofyalioglu et al., 2017; Thun & Hoenig, 2011). ISCR relates to problems in organizational boundaries, while ESCR relates to environmental factors (Gilaninia et al., 2013). Table 8 shows the type of risk in the agricultural supply chain.

Table 8 Type of risk in agricultural supply chain

No	Author(s)	Type of risk in agricultural supply chain
1	World Bank (2016)	Enabling environmental risks; production risks; market risks.
2	Jaffee et al. (2008, 2010)	Weather-related risks; natural disasters (encompassing extreme weather events); environmental and biological risks; market-related risks; infrastructural and logistical risks; operational and management risks; institutional and public policy risks; political risks.
3	Komarek et al. (2019)	Institutional risks; personal risks; production risks; market risks; financial risks.
4	Behzadi et al. (2018)	Supply-side risks; demand-side risks.
5	Nto et al. (2014)	Rice-technical risks; market risks; financial risks; political risks; social risks.
6	Lam et al. (2015)	Natural disasters and weather-related risk; environmental and biological risk; market-related risk; infrastructural and logistical risk; operational and managerial risk; institutional and government policy risk; order of risk magnitude.
7	Linn and Maenhout (2019)	Supply uncertainty; demand uncertainty; process uncertainty; planning and controlling uncertainty; competitor uncertainty; uncertainty of the grantee price from public regulation; new government uncertainty; climate uncertainty.

Table 8 (Continued)

No	Author(s)	Type of risk in agricultural supply chain
8	Rohmah et al. (2015)	Risk of product declined; risk of damage while storage; risk of demand changing; risk of machine damage while the process; risk of damage during the process; risk of processing delays; risk of supply delays; risk of containing chemical contaminants; risk of quality incapability; risk of competitor presence; risk of shortage of stock; risk of product contamination during the process; risk of damage or loss of quality; risk of goods return.
9	World Bank (2011)	Risk identification according to key rice industry stakeholders and the climatic data from the past 20 years as follows: production risks; market risks (include increasing transportation costs); other risks (regulatory risks, preferential-market-access erosion, and inaccessibility to dam roads).

1. Major risks and potential risk effects in Cambodia

The result of the prioritization (table 9) demonstrates about eight value chains out of 28 crops based on criteria, including 1) investment difficulty, 2) contribution of crops to GDP and employment, 3) contribution to growth, and 4) other criteria including Cambodian geographic spread and environmental sustainability (Goletti & Sovith, 2016).

Table 9 The prioritization of value chains and production value

Type of crop	Prioritization (Rank)	Production value in USD million (2015)
Rice	1	3,134
Maize	2	118
Cassava	3	770
Mungbean	4	76
Mango	5	334
Cashews	6	110
Pepper	7	95
Vegetables	8	199

Sources: Goletti and Sovith (2016)

Table 10 shows the scenario of the lower agricultural growth would be huge. The slow agricultural growth would also lead to much slower poverty alleviation (Eliste & Zorya, 2015). Figure 19 and 20 demonstrates the primary issues in Cambodia's agriculture.

Table 10 Effect of lower agricultural growth on indicators in Cambodia

Indicators	2012	2030	
		3 Percent average GDP growth	5 Percent average GDP growth
Contribution of agriculture in GDP (percent)	26	15	17
Contribution of agriculture in labor force (percent)	51	34	31
Productivity of agricultural labor ($/ person)	1,200	2,450	3,700
Productivity of agricultural land (USD/ ha)	1,300	1,900	2,700
Labor productivity ratio (agricultural worker/ none agricultural workers)	2.1	2.1	1.6

Sources: Eliste and Zorya (2015)

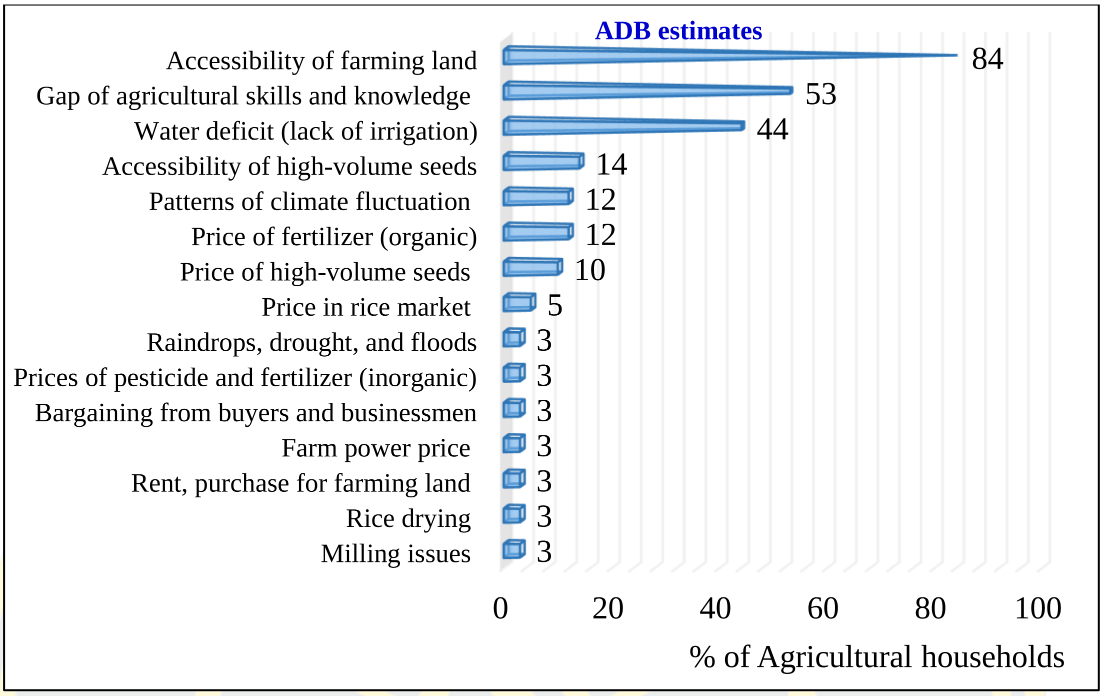


Figure 19 The major problematic constraints agricultural production-Cambodia

Sources: Asian Development Bank (2014)

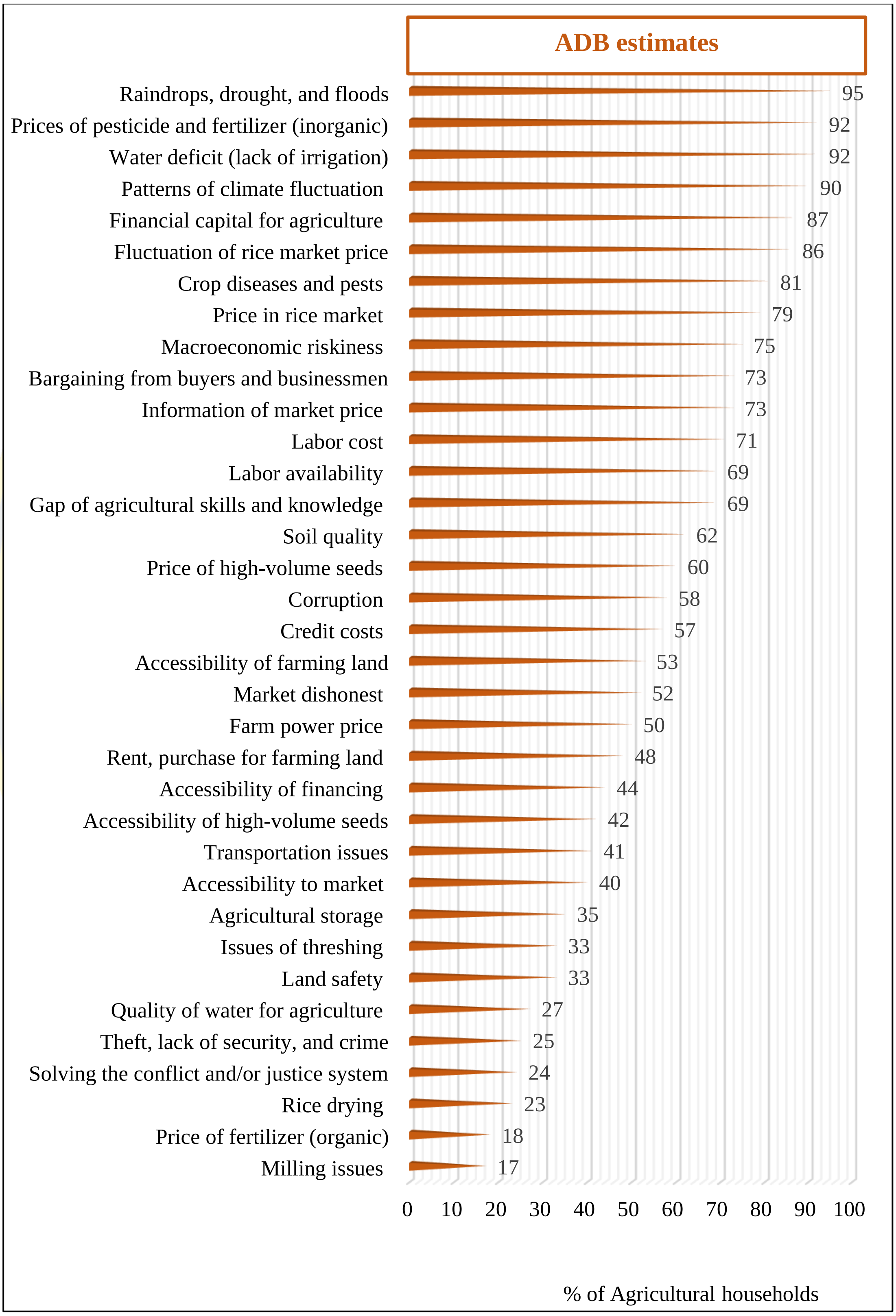


Figure 20 Farmers’ ranking of primary issues in Cambodia agriculture

Sources: Asian Development Bank (2014)

1.1 Supply risks in Cambodia

Cambodian farmers encountered many issues: in-adequate agricultural inputs, high costs of farming inputs, and lack of farm equipment (Mao et al., 2014). Normally, they were small-scale farmers, who employed a few agricultural workers and farmed seasonally to supply domestic markets. The farmers could not access loans from agricultural banks to purchase machinery and equipment; thus, they have had to use savings or borrow from dealers or financial institutions that provided high-interest rate loans (24 percent per year in Cambodia while below 1 percent per year in Vietnam). Domestic manufacturers typically produce farm equipment and machinery for small-scale farmers without sophisticated processes such as threshers, water pumps, locally made trucks for transporting, trailers, and miscellaneous spare parts. Cambodia is still importing large-scale machinery (tractors, walking tractors, etc.) from other countries like the US, China, Japan, India, Thailand, and Belorussia (Kea et al., 2016).

1.2 Production risks in Cambodia

A significant amount of rice production is lost due to biotics (e.g., weeds, pests, diseases) (Bairagi et al., 2020; Castilla et al., 2019; Chhun et al., 2019; Martin et al., 2021; Mishra, Bairagi, et al., 2018). Weeds were a significant problem for 93 percent of farmers, of which 70 percent of them claimed a yield loss of greater than 20 percent was suffered (Chhun et al., 2019). Martin (2017) demonstrated that Cambodia's average rice paddy yield at approximately 3 tons per hectare is about 50 percent of the yield potential, and losses caused by the competitions of weeds proved to be a significant issue. Castilla et al. (2019) assessed in farmers' fields the intensity of setbacks caused by biological issues (diseases, pests, and weeds) and rice yield. The results showed that most survey farmers earned lower yields than the national average of 4.03 tons per hectare, which could be attributed to the low efficiency of their crop and biological management strategies (Castilla et al., 2019).

Mishra, Bairagi, et al. (2018) investigated the impact of abiotic stress (including access to capital in rice production) on smallholders in Cambodia. The result showed that the lack of working capital because of loan inaccessibility or/ and low return could result in higher technical inefficiency in the Provinces of Cambodia

(Mishra, Bairagi, et al., 2018). According to Montgomery et al. (2017), the lack of funds was ranked by participants (research samples) as the fourth most crucial issue to production. While 34 percent of respondents listed the lack of funds as an issue to their system, 91 percent of samples had cash flow insufficiency every year.

Kea et al. (2016) illustrated that farmers applying poison to remediate grass and insects in province posed a significant negative effect on rice output. This issue could be the result of farmers' misuse of poison in rice crops; most smallholder rice farmers have little education (Kea et al., 2016), and many do not follow the guidelines for using pesticides and other chemicals. These practices result in damage to crops and also pollute or harm environmental conditions (Flor, Maat, Hadi, Then, et al., 2019; Martin, 2017).

1.3 Demand risks in Cambodia

Previous studies have identified the following issues: low prices of rice products, lack of market information, and uncertainty of market demand (Horita, 2016; Kong & Castella, 2021; Mao et al., 2014; Mishra, Bairagi, et al., 2018; Montgomery et al., 2017). An officer from the Ministry of Economy and Finance also noted that Cambodian rice millers and foreign traders usually decide the prices of farmers' rice (Horita, 2016). The research reveals that most farmers (Mao et al., 2014) did not get enough support from the government in terms of marketing. One farmer asserted that the government should help them; otherwise, most villagers will give up and migrate to another country (Mao et al., 2014).

1.4 Environmental risks in Cambodia

Rice farming in Cambodia is highly vulnerable to climate change (drought and floods) and weak infrastructure (Dalgliesh et al., 2016; Mao et al., 2014; Mishra, Bairagi, et al., 2018; Sithirith, 2017). Cambodia has abundant water resources in the rainy season and water scarcity in the dry season; this poses an enormous problem for long-term development (Sithirith, 2017). Drought significantly affects rice farming inefficiency in Cambodia (Mishra, Bairagi, et al., 2018). The over-abundance of water in the rainy season causes frequent floods and damage; thus, the operation and maintenance of large-scale irrigation systems are inadequate (Sithirith, 2017). Cambodian farmers can primarily grow rice only once per year due to the lack of irrigation systems and good water management practices (Kea et al., 2016). In fact, farmers lack not only irrigation systems but also basic infrastructure such as roads and electricity (Mao et al., 2014).

Table 11 illustrates that Cambodia has experienced flooding according to the Provincial Committee for Disaster Management (PCDM) from 05-09-2019 to 18-09-2019, as cited in World Food Programme DanChurchAid (2019). The flood impacts livelihood such as households (89,046), household displaces (12,993), deaths (14), houses (60,593), health centers (23), schools (264), roads (734,382), and agricultural land (42,239).

Table 11 Affected by flood to livelihood in Cambodia

Affected by flood to livelihood in Cambodia (Sep-2019)									
Nₒ.P	**PCDM report date**	**Household**	**Household displaces**	**Deaths**	**Houses**	**Health centers**	**Schools**	**Length of road (m)**	**Agriculture land (h)**
[P1]	18th	1,169	n/ a	n/ a	1,166	n/ a	n/ a	584	1,533
[P2]	17th	29,286	1,253	7	22,803	5	73	216,611	6,391
[P3]	16th	1,036	406	n/ a	511	n/ a	17	8,228	1,477
[P4]	12th	20,078	2,603	4	20,078	8	80	134,696	6,657
[P5]	5th	26	n/ a	-	26	n/ a	n/ a	1,693	383
[P6]	9th	2,156	28	1	1,962	-	5	21,880	5,571
[P7]	18th	5,634	168	-	5,926	3	39	142,102	11,444
[P8]	18th	n/ a	n/ a	n/ a	n/ a	n/ a	n/ a	3,150	n/ a
[P9]	16th	9,286	3,509	-	8,121	7	50	205,438	8,782
[P10]	12th	20,375	5,026	2	-	n/ a	n/ a	n/ a	n/ a
		89,046	**12,993**	**14**	**60,593**	**23**	**264**	**734,382**	**42,239**

Note: Provinces included [P1]: Battambang; [P2]: Kampong Cham; [P3]: Kampong Thom; [P4]: Kratié; [P5]: Oddar Meanchey; [P6]: Preah Vihear; [P7]: Prey Veng; [P8]: Pursat; [P9]: Steung Treng; [P10]: Tboung Khmum

Sources: PCDM (2019), as cited in World Food Programme DanChurchAid (2019)

The Royal Government of Cambodia planned at least 1 million ton for rice export in 2015, but the kingdom did not achieve that in its planning (exported rice products only amounted to 538,396 tons in 2015). There are many reasons for this outcome: First, the Royal Government of Cambodia (RGC) does not have the ability and cannot support rice farmers to produce large-scale rice production. Second, the RGC hasn't formulated policies or have the ability to buy rice products to stock in the warehouse for export. Third, the RGC does not have the ability to manage the national market. Fourth, the RGC does not impose policies that manage traders or private companies in purchasing rice products from farmers. Fifth, the RGC is still not in control of rice import and export (Bunnarith, 2016).

During the coronavirus crisis, the Royal Government of Cambodia permitted only the export of fragrant rice, but the government reserved other types for domestic sales to ensure local food safety. Indeed, the Covid-19 pandemic is the issue, and as a result, Cambodian farmers decrease agricultural products in Cambodia and negatively affect the farmers' livelihoods (Hossain, 2018b).

1.5 Risk factors in Cambodia and other countries

Analysis of the existing studies enabled identification of 4 risk categories mentioned across the literature: supply risks, production risks, demand risks, and environmental risks (Figure 21). Our results show the 18 risk factors and the frequency of indications in articles (e.g., factor 14, natural disasters, was mentioned most often), as demonstrated in Table 12.

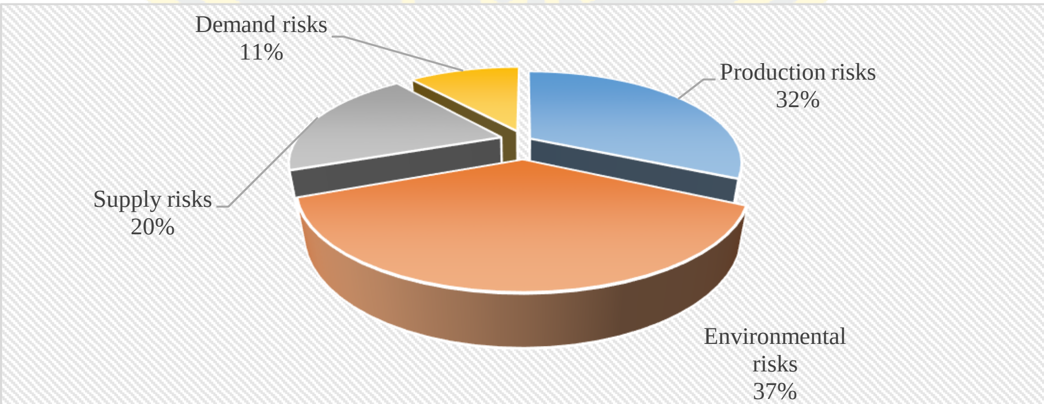


Figure 21 Frequency of risks in the sample

Table 12 Classification of significant risks facing rice supply chains

Risk factors in rice supply chain	Count
The factors of supply risks	
1. Rising costs of raw materials (fertilizer, pesticide, high yield seeds, fuel)	10
2. Rising costs of services (transportation, labor, interest rates or/ and credit, other agricultural services)	10
3. Lack of high yield seeds	7
4. Lack of labor	21
5. Lack of equipment and machinery	4
The factors of production risks	
6. Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)	34
7. Lack of financial capital	8
8. Misuse of fertilizer or/ and pesticide	16
9. Lack of agricultural know-how	24
The factors of demand risks	
10. Low prices of rice products	11
11. Lack of market information	6
12. Uncertainty of market demand for quantity	4
13. Uncertainty of market demand for quality or/ and food safety requirements	5
The factors of environmental risks	
14. Natural disasters (flood, drought)	48
15. Lack of irrigation systems	19
16. Lack or poor condition of basic infrastructure (roads, electricity)	9
17. Inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services)	13
18. Pandemic risks (Covid-19)	9

Table 13 Articles by factors

No	Author(s)	Risk factors	No	Author(s)	Risk factors
1	(Alam et al., 2020)	14	51	(Martin, 2017)*	4, 6, 9, 14
2	(Arouna et al., 2021)	14	52	(Martin et al., 2021)*	2, 4, 6, 8, 9, 14, 15
3	(Awotide et al., 2016)	3	53	(Middendorf et al., 2021)	18
4	(Ayanlade et al., 2017)	14	54	(Milovanovic & Smutka, 2018)	6
5	(Ba et al., 2019)	9	55	(Mishra, Bairagi, et al., 2018)*	1, 2, 3, 7, 9, 11, 14, 15
6	(Bairagi et al., 2020)*	6, 14	56	(Mishra, Kumar, et al., 2018)	6, 14
7	(Cabasan et al., 2019)	3, 4, 6, 7, 8, 14	57	(Mohammad Sharif et al., 2018)	8
8	(Castilla et al., 2019)*	6, 9	58	(Montgomery et al., 2017)*	3, 4, 6, 7, 10, 14, 15
9	(Chen et al., 2018)	8	59	(Muhammad Khalid et al.,2020)	14
10	(Ches & Yamaji, 2016)*	2, 4	60	(Mulvaney & Krupnik, 2014)	6
11	(Chhun et al., 2019)*	6, 9	61	(Munandar & Lubis, 2021)	7, 11, 14
12	(Connor et al., 2020)	9, 14	62	(Mzyece & Ng'ombe, 2021)	14
13	(Cox et al., 2019)	1, 2, 4, 6, 10, 14, 15, 17	63	(Nesterenko et al., 2021)	18
14	(Dalgliesh et al., 2016) *	1, 2, 14	64	(Nguyen et al., 2015)	6
15	(Dang et al., 2019)	9	65	(Nguyen et al., 2019)*	4, 6, 14, 15, 16
16	(Dany et al., 2015)*	14, 17	66	(Nguyen et al., 2021)	4
17	(Demont & Rutsaert, 2017)	5, 13, 14, 16, 17	67	(Nurmalinda et al., 2021)	4, 6, 14, 15
18	(Donkor et al., 2018)	6	68	(Orlando et al., 2020)	6, 9, 14
19	(Donkor et al., 2021)	11	69	(Paganini et al., 2020)	18
20	(Faysse et al., 2020)	4, 9, 14, 15	70	(Pervez et al., 2019)	1, 3, 10
21	(Flor et al., 2018)*	4, 6, 8, 14, 17	71	(Putra et al., 2020)	9, 14, 16

Table 13 (Continued)

No	Author(s)	Risk factors	No	Author(s)	Risk factors
22	(Flor, Maat, Hadi, Kumar, et al., 2019)*	6, 8	72	(Rachman et al., 2021)	9
23	(Flor, Maat, Hadi, Then, et al., 2019)*	6, 8, 9	73	(Rigg et al., 2020)	4, 9
24	(Fukai et al., 2019)	2, 4	74	(Rohmah et al., 2015)	12
25	(Gates, 2015)	18	75	(Ruengdet & Wongsurawat, 2015)	10
26	(Gates, 2020)	18	76	(Rugema Semaana, Sseguya, et al., 2017)	11
27	(Gaviglio et al., 2021)	17	77	(Rugema Semaana, Kibwika, et al., 2017)	5, 9, 14
28	(Goyol & Pathirage, 2018)	1, 2, 6, 14, 16	78	(Sankoh et al., 2016)	6, 8, 9, 17
29	(Grunfeld & Ng, 2013)*	9	79	(Saqib et al., 2016)	14
30	(Hadizadeh et al., 2018)	15	80	(Sathapatyanon et al., 2018)	1, 2, 10, 11, 12, 13
31	(Hamer et al., 2020)	16	81	(Sayeda et al., 2021)	4, 10, 14, 18
32	(He et al., 2021)	14	82	(Schreinemachers et al., 2015)*	8, 9, 17
33	(Higgins et al., 2021)	15	83	(Schuch et al., 2021)*	15
34	(Horita, 2016)*	10, 12, 13	84	(Seng, 2014)*	4, 6, 14, 15
35	(Hossain, 2018b)*	18	85	(Sithirith, 2017)*	15
36	(Iwahashi et al., 2021) *	4, 6, 14, 15	86	(Soe Paing & Usami, 2020)	17
37	(Jiang et al., 2019)	14	87	(Suresh et al., 2021)	14, 18
38	(Kabir et al., 2020)	6	88	(Suwanmontri et al., 2018)	14
39	(Kadigi et al., 2020)	14	89	(Thi Lam et al., 2018)	7
40	(Kassem & Bader Alhafi, 2020)	8	90	(Tran, 2020)	4, 7, 9, 14, 15, 16, 17

Table 13 (Continued)

No	Author(s)	Risk factors	No	Author(s)	Risk factors
41	(Kea et al., 2016)*	2, 5, 6, 7, 8, 9, 14, 15, 16, 17	91	(Tran et al., 2021)	1, 4, 6, 8, 10, 14, 15
42	(Kong & Castella, 2021)*	10, 14	92	(Turner et al., 2017)*	3, 9
43	(Kulyakwave et al., 2019)	3, 9, 14	93	(Usami, 2019)	14
44	(Lam et al., 2015)	13	94	(Varshney et al., 2021)	18
45	(Le et al., 2020)	6	95	(Vo Hong et al., 2018)	1, 6, 8, 14, 15, 17
46	(Le Truc et al., 2019)	4, 8, 9	96	(Wokker et al., 2014) *	6, 14
47	(Liman Harou et al., 2021)	6	97	(Xangsayasane et al., 2019) *	2, 4, 6
48	(Linn & Maenhout, 2019)	12, 13, 14, 17	98	(Xu et al., 2021)	14
49	(Liu et al., 2020)	6, 14	99	(Zandi et al., 2020)	1, 6, 10, 14, 15, 16
50	(Mao et al., 2014) *	1, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17	100	(Zhou et al., 2020)	8

Note: * Demographic information: Cambodia (the authors' country or the authors' collected data and reported data)

The researcher identified different risk factors across the 100 samples of 128 articles (Table 13). Analysis of the frequency of mention illustrated that environmental risks occurred most often in the literature, mentioned in 64 of 100 articles, followed by production risks (55/ 100), supply risks (34/ 100), and demand risks (19/ 100). The frequency of mention did not significantly reflect the risk prioritization. The risk prioritization in the supply chain relied on the highest risk to the lowest risk in terms of probability of occurrence, the severity of effect, etc. (Rohmah et al., 2015). Thus, the frequency analysis showed that some risk factors commonly illustrated in the agricultural supply chain.

2. Approach of risk prioritization in agricultural supply chain

Risk prioritization is employed to analyze the degree of risk related to each hazard (Faizal & Palaniappan, 2014). The degree of risk relied on two primary factors 1) the severity of the effects, and 2) the likelihood in which risk occurs [risk = f(severity, likelihood)] (Chang et al., 2015; Christopher & Peck, 2004; Jaffee et al., 2010; Thun & Hoenig, 2011; World Bank, 2016) (see Figure 22 and Table 14).

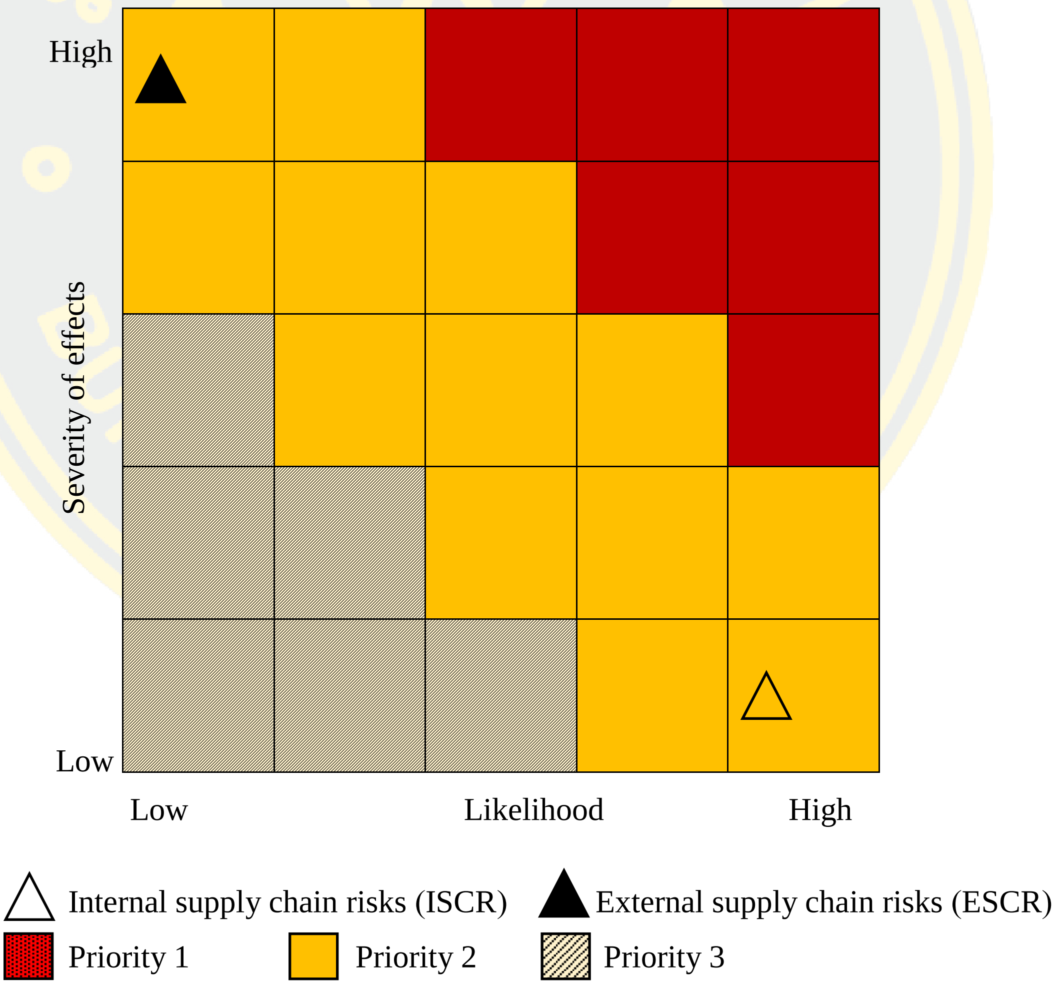


Figure 22 Prioritization matrix of risk

Sources: Thun & Hoenig (2011)

Table 14 Risk categorization: likelihood of event and severity of effects

Likelihood	Indicator	Effects	Indicators
Highly probable	Within 2-year period	Catastrophic	> 50 percent losses
Probable	Within 5-year period	Critical	From 30 percent to 50 percent
Occasional	Within 10-year period	Considerable	From 15 percent to 30 percent
Remote	Within 20-year period	Moderate	From 5 percent to 15 percent
Improbable	Within 40-year period	Negligible	< 5 percent losses

Sources: World Bank (2016)

The table 15 demonstrates the matrices of risk prioritization in Malawi Country for all crops (cotton, sugarcane, tea, tobacco, maize, food crops, and export crop).

Table 15 Matrix of risk prioritization for all crops in Malawi Country

Effect PBTY	Moderate	Considerable	Critical	Catast-Rophic
Highly probable (1 in 3 years)	- Hail storms - Untimely distribution of inputs (C) - Theft (S, TE, FC) - Damage due to wild animals - Outage of power (S, TE) - Exchange rate	- Pests and diseases (FC, EC) - Price uncertainty and volatility (TO, TE, C, S) - Uncertain regulatory environment for traders	- Drought: high temperatures, extension of dry spells, false start of wet season, and short wet season	

Table 15 (Continued)

Effect PBTY	**Moderate**	**Considerable**	**Critical**	**Catast-Rophic**
Probable (1 in 5 years	- Side-selling (C) - Excess rainfall at harvest and cost for processing (TE, S)-Flood (FC)		- Uncertain market interventions causing price volatilities (M)	
Occasional (1 in 10 years)		- Rejection of export shipments (TO)		

(C) = Cotton; (S) = Sugarcane; (TE) = Tea; (FC) = Food Crops;
(EC) = Export Crop; (TO) = Tobacco; (M) = Maize (World Bank, 2016)

World Bank (2011) conducted a study on risk prioritization of the rice supply chain in Guyana. The researchers interviewed and reviewed the rice sector and climatic data from the past 20 years in detail (Table 16). (World Bank, 2011)

Table 16 Summary of risks: Likelihood of event vs. severity of effects in Guyana

		Severity of effects				
		Negligible	Moderate	Considerable	Critical	Catast-rophic
Likelihood of events	Highly probable			- Delayed payment	- Flood	
	Probable		- Rise in input price (fertilizer, chemicals, diesel, etc.) - Price risk - Inaccessibility to dam roads	- Significant increase in red rice - Paddy bug	- Water scarcity for irrigation	

Table 16 (Continued)

		Severity of effects				
		Negligible	Moderate	Considerable	Critical	Catast-rophic
Likelihood of events	Occasional		- Rise in transportation cost - Excess rainfall at harvest	Blast (rice fungus) Regulatory risk Erosion in preferential market access		
	Remote					
	Improbable					

Sources: World Bank (2011)

3. Sustainable performance in agricultural supply chain

Sustainable performance refers to consideration of the dimension of environmental performance, the dimension of social performance, and the dimension of economic performance (Chhay et al., 2017; Demont & Rutsaert, 2017; Krishnan et al., 2020; Liu et al., 2020; Okpiaifo et al., 2020; Röder et al., 2020; Tran et al., 2021; Zeweld et al., 2019). We discovered that the economic performance holds a considerable percentage of all performance types, while other performance clusters earned limited considerations, particularly environmental performance (Table 17).

Table 17 Articles by performances

No	Sources	Performance	No	Sources	Performance
1	(Abdul-Rahaman et al., 2021)	7	39	(Martin et al., 2021)	7
2	(An, 2021)	7	40	(Milovanovic & Smutka, 2018)	4
3	(Arouna et al., 2021)	3, 7	41	(Minten et al., 2013)	8
4	(Arunrat et al., 2021)	3	42	(Mishra, Bairagi, et al., 2018)	5, 7, 8

Table 17 (Continued)

No	Sources	Performance	No	Sources	Performance
5	(Awotide et al., 2016)	7	43	(Mishra, Kumar, et al., 2018)	7
6	(Bairagi et al., 2020)	7	44	(Monjardino et al., 2020)	4, 7
7	(Bidzakin et al., 2019)	7	45	(Montgomery et al., 2017)	2, 7
8	(Braun et al., 2019)	2, 3	46	(Mounirou, 2020)	6, 8
9	(Cabasan et al., 2019)	4, 5	47	(Muhammad Khalid et al., 2020)	4, 5, 7
10	(Castilla et al., 2019)	7	48	(Mukhopadhyay, 2021)	7
11	(Chandra & Diehl, 2019)	4	49	(Mulvaney & Krupnik, 2014)	3
12	(Ches & Yamaji, 2016)	7	50	(Munandar & Lubis, 2021)	4, 5
13	(Chhay et al., 2017)	6, 7, 9	51	(Nguyen et al., 2015)	7
14	(Chhun et al., 2019)	7	52	(Nguyen et al., 2018)	2
15	(Connor et al., 2020)	3	53	(Nguyen et al., 2019)	2, 8
16	(Dalgliesh et al., 2016)	2, 4, 7	54	(Nurmalinda et al., 2021)	8
17	(Demont & Rutsaert, 2017)	2	55	(Ojo et al., 2021)	7
18	(Dewi et al., 2015)	7	56	(Okpiaifo et al., 2020)	2, 3, 7, 8
19	(Donkor et al., 2018)	7	57	(Orlando et al., 2020)	7
20	(Flor et al., 2018)	6	58	(Paganini et al., 2020)	4, 5, 6
21	(Fusi et al., 2014)	1, 3	59	(Putra et al., 2020)	4, 7

Table 17 (Continued)

No	Sources	Performance	No	Sources	Performance
22	(Goyol & Pathirage, 2018)	4, 5, 7, 9	60	(Rachman et al., 2021)	4
23	(He et al., 2021)	2, 3	61	(Rambonilaza & Neang, 2019)	3, 7, 8
24	(Higgins et al., 2021)	5	62	(Röder et al., 2020)	3, 4
25	(Iwahashi et al., 2021)	7	63	(Rugema Semaana, Kibwika, et al., 2017)	7
26	(Jiang et al., 2019)	7	64	(Sankoh et al., 2016)	3, 7, 8
27	(Kadigi et al., 2020)	4, 5, 6, 7, 9	65	(Sayeda et al., 2021)	4, 7
28	(Kea et al., 2016)	7	66	(Sithirith, 2017)	7
29	(Krishnan et al., 2020)	9	67	(Soullier & Moustier, 2018)	4, 7
30	(Kulyakwave et al., 2019)	7	68	(Srisopaporn et al., 2015)	8
31	(Kumar et al., 2020)	3	69	(Suwanmontri et al., 2018)	3, 7
32	(Le et al., 2020)	7	70	(Thanawong et al., 2014)	1, 2, 3, 7, 9
33	(Lee et al., 2020)	1, 2, 4	71	(Tran, 2020)	7
34	(Liman Harou et al., 2021)	7	72	(Vo Hong et al., 2018)	1, 2, 3, 7, 8, 9
35	(Mabe et al., 2019)	7	73	(Wesana et al., 2018)	8
36	(Maertens & Vande Velde, 2017)	4, 8	74	(Wokker et al., 2014)	7
37	(Mao et al., 2014)	5	75	(Zeweld et al., 2019)	2, 4, 5, 7
38	(Martin, 2017)	7	76	(Zhou et al., 2020)	3

Some of the nine observed variables indicate related contexts or similar concepts. The number of observed variables had to be clustered to improve the results accuracy and analysis efficiency. Then, nine observed variables were consolidated into three latent variables (Figure 23). Environmental performances encompass the consumption rate of energy (electricity and oil), the consumption rate of natural resources (water and land), and environmental pollutants (water, land, and air). Social performances are food insecurity (the scale of accessibility to foods and eating patterns), poverty, and farmers' knowledge. Economic performances include the rice yield of farming households, rice quality (nutritional benefits, softness, aroma, and physical appearance), and return on investment (ROI) (Figure 23).

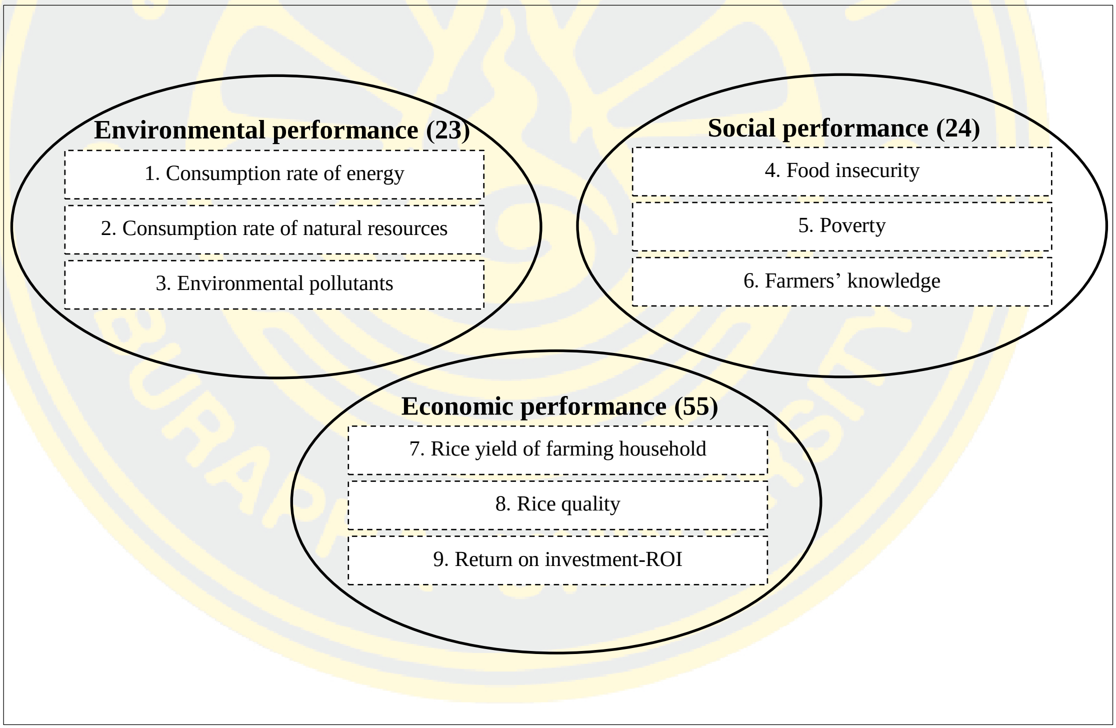


Figure 23 Three clusters of sustainable performance in the literature of the RSC

4. Risk management strategies

Risk management strategies can be articulated as ex-ante or ex-post approaches. Ex-ante actions occur before a risk event happens, and ex-post management strategies occur after people have been made aware of it (Jaffee et al., 2010; World Bank, 2016). Table 19 illustrates the risk management strategies for rice supply chains.

The third output of this study is to propose appropriate solutions, which include ex-ante risk management strategy (risk mitigation, risk avoidance, risk transfer) and ex-post risk management strategy (risk coping) (Table 18). Risk mitigation refers to plans aimed at reducing the effects of the risks and/ or lessening the likelihood of such occurrence; risk avoidance occurs when there are high risks (APICS, 2017). Additionally, when stakeholders can transfer risks from one party to another party or process, risk transfer (e.g., agricultural insurance) occurs (Alam et al., 2020; APICS, 2017; Soullier & Moustier, 2018; Usami, 2019). Moreover, risk coping is needed to help rescue stakeholders from the situations in which they may find themselves following adverse effects and better absorb them. Risk coping strategies include likelihood recovery programs, donations (in-kind or cash), etc. Quick interventions are often financially beneficial and reduce loss (World Bank, 2016). Table 18 shows the tasks of supply chain risk management given by researchers.

Table 18 Tasks of supply chain risk management given by researchers

No	Authors	Tasks of supply chain risk management
1	Lam et al. (2015)	Identify risks on the demand side and supply side of the chain, assess risks based on value chain analysis, and manage the rice supply chain risks
2	Rohmah et al. (2015)	Assess risks in terms of probability of occurrence, severity effect, and likelihood of detection in the organic rice supply chain
3	Zandi et al. (2020)	Identify risks; assess risks via three factors: Severity, occurrence, and detectability; manage risks in the agricultural supply chain

Table 18 (Continued)

No	Authors	Tasks of supply chain risk management
4	Linn and Maenhout (2019)	Identify the sources of uncertainty, investigate environmental uncertainty on the performance of the rice supply chain, and propose risk management strategies
5	Xu et al. (2021)	Identify the factors that affect the resilience and manage risks in the agricultural supply chain regarding water resources use

Table 19 Risk management strategies for rice supply chains

Risk management strategies	Tools	Stakeholders
Risk management strategies for supply risks		
Seek alternative suppliers’ (AF)	RM; RC	Farmers; Related stakeholders
Promote contract farming’ (I); (AD)	RT; RM	MAFF; Farmers; Related stakeholders
Provide the incentive to local seed producers and distributors’ (M); (AI); (AQ); (AU)	RM	MAFF; Related stakeholders
Use the system of “sharing-hand”: help each other during the farming period; improve agricultural management practices (e.g., using direct seeding)’ (F); (X); (AC)	RM; RC	Farmers; Related stakeholders
Offer tax incentives to incentivize the imports of equipment and machinery’ (AJ)	RM	MEF; Related stakeholders

Table 19 (Continued)

Risk management strategies	Tools	Stakeholders
Risk management strategies for production risks		
Improve agricultural management practices for biological risks (e.g., better water management, improve seeds); improve the agricultural extension services to commune level’ (B); (D); (E); (O); (Q); (AA); (AC); (AU)	RM; RC	Farmers; MAFF; Related Stakeholders
Encourage agricultural microfinance’ (A); (M); (AA); (AU)	RM	MEF; NBC; Related stakeholders
Encourage and promote policy on sustainable utilization of farming land (e.g., effective mapping)’ (AA); (AR); (AU)	RM	MLMUPC; MAFF; MOP: National Institute of Statistics of Cambodia-NIS; Related stakeholders
Develop public policies and enforce regarding sanitary and phytosanitary standards (e.g., food safety); use pesticide and fertilizer effec-tively; avoid risky practices through organic farms’ (B); (C); (P); (R); (AL); (AN); (AU)	RC; RM; RA	MAFF; MISTI; MOH; MOC; Farmers; Related stakeholders
Improve productivity by using high-yielding seed and modern agricultural techniques’ (B); (E); (M); (AU)	RM; RC	MAFF; Farmers; Related stakeholders
Support and establish Farmer Organization’ (AM); (AU)	RM; RC	MAFF; Related stakeholders
Improve agricultural training’ (AA); (AH); (AK); (AU)	RM; RC	MAFF; Related stakeholders

Table 19 (Continued)

Risk management strategies	Tools	Stakeholders
Risk management strategies for demand risks		
Conduct comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers’ (AU)	RM	MOC; MAFF; Related stakeholders
Improve transparency and market information’ (W); (AG); (AO); (AU)	RM; RC	MAFF; Related stakeholders
Promote contract farming with millers/ buyers’ (I); (AB); (AE)	RT; RM	MAFF; Farmers; Related stakeholders
Improve warehouse management’ (AI); (AM); (AU)	RM; RT	Farmers; Related stakeholders
Seek alternative buyers’ (AF)	RM; RC	MAFF; Farmers; Related stakeholders
Adapt for climate change (e.g., agricultural diversification); purchase insurance; aid or charity from government, international organization, and other donors’ (F); (G); (H); (M); (N); (O); (W); (Y); (AP); (AU)	RT; RM; RC	Farmers; Related Stakeholders
Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)’ (J); (K); (M); (S); (T); (Z); (AU)	RM; RC	MOWRAM; MFAIC; Farmers; Related stakeholders
Construct and maintain roads in the countryside (link rice production areas to markets)’ (V); (W); (AA); (AU)	RM; RC	MRD; MPWT; Related stakeholders

Table 19 (Continued)

Risk management strategies	Tools	Stakeholders
Risk management strategies for demand risks		
Reduce electricity price and promote electric power transmission to rural areas’ (M); (V); (AU)	RM; RC	MISTI; MME: Electricity Authority of Cambodia-EAC; Related stakeholders
Improve the agricultural extension services to commune level’ (B); (L); (S); (AU)	RM; RC	MAFF; Related stakeholders
Improve agricultural know-how training’ (B); (M); (O); (Q); (S); (U); (AU)	RM; RC	MAFF; Related stakeholders
Manage Covid-19 affects farmers by investing in the vaccination program, quarantine program, robust health systems, advanced R & D’ (AS); (AT)	RM; RC	MOH; Related stakeholders

Note 1: Reference: A-Saqib et al. (2016); B-Schreinemachers et al. (2015); C-Zeweld et al. (2019); D-Castilla et al. (2019); E-Chhun et al. (2019); F-Dalgliesh et al. (2016); G-Alam et al. (2020); H-Ayanlade et al. (2017); I-Ba et al. (2019); J-Hadizadeh et al. (2018); K-Higgins et al. (2021); L-Le et al. (2020); M-Mishra, Bairagi, et al. (2018); N-Soullier and Moustier (2018); O-Montgomery et al. (2017); P-Flor, Maat, Hadi, Kumar, et al. (2019); Q-Martin (2017); R-Rambonilaza and Neang (2019); S-Nguyen et al. (2019); T-Sithirith (2017); U-Chhay et al. (2017); V-Mao et al. (2014); W-Linn and Maenhout (2019); X-Ches and Yamaji (2016); Y-Jiang et al. (2019); Z-Wokker et al. (2014); AA-Kea et al. (2016); AB-Zandi et al. (2020); AC-Flor et al. (2018); AD-Bidzakin et al. (2019); AE-Liu et al. (2020); AF-Donkor et al. (2021); AG-Munandar and Lubis (2021); AH-Grunfeld and Ng (2013); AI-Sayeda et al. (2021); AJ-Fukai et al. (2019); AK-Kulyakwave et al. (2019); AL-Donkor et al. (2018); AM-Rugema Semaana, Kibwika, et al. (2017); AN-Mohammad Sharif et al. (2018);

AO-Rugema Semaana, Sseguya, et al. (2017); AP-Usami (2019); AQ-Awotide et al. (2016); AR-Suresh et al. (2021); AS-Gates (2015); AT-Gates (2020); AU-Turner et al. (2017)

Note 2: RM, risk mitigation; RA, risk avoidance; RT, risk transfer; RC, risk coping

Note 3: (1) Ministry of Agriculture, Forestry and Fisheries (MAFF); (2) Ministry of Commerce (MOC); (3) Ministry of Economy and Finance (MEF); (4) Ministry of Foreign Affairs and International Cooperation (MFAIC); (5) Ministry of Health of Cambodia (MOH); (6) Ministry of Industry, Science, Technology and Innovation (MISTI); (7) Ministry of Land Management, Urban Planning and Construction (MLMUPC); (8) Ministry of Mines and Energy (MME); (9) Ministry of Planning (MOP); (10) Ministry of Public Works and Transport (MPWT); (11) Ministry of Rural Development (MRD); (12) Ministry of Water Resources and Meteorology (MOWRAM); (13) National Bank of Cambodia (NBC); (14) Farmers; (15) Related Stakeholders

5. Research gap from the literature review

This section demonstrates the relevant issues that have been published (Table 20). This process aims to find the research gap and make this study publishable without duplicating the existing research.

Table 20 Research gap from the literature review

No	Reference	Addressed issues
[1]	(Biswas et al., 2015)	Farmers' perception, identification, assessment, and alleviation practices in Bangladesh toward disaster risk and climate change effects involving agriculture.
[2]	(Castilla et al., 2019)	A relationship analysis and characterization on yield diversification, cropping constraints (weeds, rodents, pests, diseases), and farming practices of Cambodia rice.

Table 20 (Continued)

No	Reference	Addressed issues
[3]	(Chhun et al., 2019)	Quantification, farmers' knowledge, and the effects on weed management practices of Northwest Cambodia rice.
[4]	(Dalgliesh et al., 2016)	Improving resilience of Cambodia rice ecosystems-evaluating cropping options, identifying strategies and technologies, mitigating the impact of seasonal climate variability.
[5]	(Erban & Gorelick, 2016)	The shortage of irrigation in the Cambodia Mekong River.
[6]	(Flor, Maat, Hadi, Kumar, et al., 2019)	Cambodia farmers' agronomic practices in Mekong Delta: pest effects, pest assessment, pest management. The factors include profits, yields, and agricultural characteristics.
[7]	(Flor, Maat, Hadi, Then, et al., 2019)	A pesticide lock-in situation of Cambodia farmers, integrated rice pest management, and rice farmers' interactions for a pesticide lock-in.
[8]	(Martin, 2017)	The study of weedy rice in Cambodia: issues-increased climate change and agricultural labor migration, challenges related to upland crops (include rice), and opportunities for developing weed management.
[9]	(Mishra, Bairagi, et al., 2018)	Assessment of rice farmers' performance, investigation on the impact of submergence and drought, capital accessibility in rice production, and stress-tolerant on technical efficiency in Cambodia: by using stochastic frontier analysis.

Table 20 (Continued)

No	Reference	Addressed issues
[10]	(Miyan, 2015)	The effects of climate variability-droughts and paradigms to migrate them in LDCS of Asian (Cambodia, Lao, Myanmar, Bangladesh, Bhutan, Nepal, Afghanistan, and Yemen): sustainability and vulnerability.
[11]	(Montgomery et al., 2017a)	The rotation of upland crop: crop yields and profits in Northwest Cambodia
[12]	(Montgomery et al., 2016)	Time of sowing and choice of the upland crop in Northwest Cambodia
[13]	(Montgomery et al., 2017)	The primary constraints to production of the upland crop: perception and knowledge regarding agricultural practices in Cambodia
[14]	(Poulton et al., 2016)	Evaluation of adapted strategies to recover quickly from climate risks related to lowland rice farming in Cambodia: using the model of APSIM-agricultural production systems simulator.
[15]	(Schreinemachers et al., 2017)	The research is to clearly understand stakeholders' knowledge in terms of positive association and negative association regarding pesticide practices, attitudes, pesticide risks, and integrated pest management in agriculture: a case study in Cambodia, Laos, and Vietnam.
[16]	(Srean et al., 2018)	Identifying constraint factors, influencing rice farming and rice yield, educational guess on profit from rice production in Battambang of northwest Cambodia

Table 20 (Continued)

No	Reference	Addressed issues
[17]	(Touch et al., 2016)	The research is to know farmers' understanding, behavior, and actual practices involving climate change; the study is also to engage with perceptions on climate change fluctuation, constraints of crop production, optional adaptation and coping with current and future climate variability: the case study of smallholder farms in Cambodia-wet tropic region.
[18]	(Bunthan et al., 2018)	Cambodian rice farming of aromatic and non-aromatic: Analysis of characteristics, affected economic factors and non-economic factors, profits, and costs of rice productions.
[19]	(Chung et al., 2019)	Using the rainfall–runoff–inundation model (RRI model) for assessing flood damage to rice paddy in Stung Sen River Basin of Cambodia
[20]	(Kea et al., 2017)	Technical efficiency (TE) measurement and identification of key effecting factors at national and rice farmer levels: using the Stochastic Frontier Analysis (SFA) model and methodology to explain rice productivity and profitability in Cambodia
[21]	(Shrestha et al., 2017)	To quantify the effects of future and current climate variability on crop production, rice production, and water footprint in Thailand.
[22]	(Ge et al., 2015)	To identify policies and strategies to mitigate supply chain risks involving grading of wheat in Canada
[23]	(Pervez et al., 2019)	Assessing market risks of hybrid rice faced by farmers in Bangladesh: using the fuzzy-Likert scale.
[24]	(Sweetman, 2015)	Investigation on pesticide consumption in farms and the critical impacts on stakeholders and the environment in Sierra Leone.

Table 20 (Continued)

No	Reference	Addressed issues
[25]	(Zeweld et al., 2019)	Sustainable practices in agriculture, management in environmental risk, making livelihood better in Northern Ethiopia
[26]	(Suvedi et al., 2018)	Carefully evaluation of core skills in agricultural development: a case study in Cambodia. It includes assessing competency levels and perceived significance, identifying gaps in competencies, and identifying appropriate solutions for extension core competencies of agricultural workers.
[27]	(Friel et al., 2013)	The policy of trade, treaties of investment, and agreements of free trade: critical risks to food-related public health (nutrition and health inequity).
[28]	(Pe'er et al., 2014)	Biodiversity failure due to agricultural reform in the EU.
[29]	(Mao, 2015)	A two-step qualitative methodology was adopted for the research on linking agriculture and tourism: The case study in Siem Reap-Angkor region of Cambodia. In the first phase, identifying the key factors of constraints and in the second phase, rating the constraints.
[30]	(Muthayya et al., 2014)	Rice commercial, international rice production, supply, milling, and consuming: fortifying vitamin and mineral deficiency.
[31]	(Yeboah et al., 2014)	To identify risks, to know the probability and severity of risks, to probe stakeholders' abilities to control for the agricultural supply chain in Ghana
[32]	(Bairagi & Mohanty, 2018)	Analysis of price through the rice value chain in Cambodia: farm price, wholesale price, and retail price.
[33]	(Linn & Maenhout, 2019)	The study is to identify environmental uncertainty, evaluate the performance, and study the effects of uncertainty on the rice supply chain: research location is located in the Ayeyarwaddy Region, Myanmar.

Table 20 **(Continued)**

No	Reference	Addressed issues
[34]	(Bachev, 2013)	A qualified framework for evaluating risk management in the Agrifood Sector. It includes the type of risks, identification of risk factors, and challenges of risks. Besides, it involves modes of management (market, private, and public), strategies, intervention, management, and opportunity.
[35]	(Komarek et al., 2019)	Know and need to know the primary type of agricultural risks, impacts, policies, and strategies to handle them.
[36]	(Maertens & Vande Velde, 2017)	An analysis of the effects of farmers' participation in a scheme of contract-farming in the food supply chain: the research of rice in Benin.
[37]	(Schreinemachers et al., 2015)	Challenge identification and risk reduction from agricultural pesticides- pesticide trade expansion, high satisfaction from farmers with integrated pest management, highlights on public policies and regulations of pesticide in Southeast Asia (developing countries)
[38]	(Azfar et al., 2014)	A conceptual framework for the supply chain to measure performance: paradigms for key practices and a clear strategy.
[39]	(Aghapour et al., 2017)	Supply chain risks management of manufacturing small-to-medium enterprises (SME) in Iran: Risks identification, subsequent risk assessment, risk mitigation by using the SCOR model, and PLS-SEM to evaluate operational performance.
[40]	(Bavarsad et al., 2014)	The impact of supply chain risk (related to macroeconomics and finance) on organizational performance in Iran.
[41]	(Chandra, 2015)	Risk investigation impacting project success in Surabaya by using the structural equation model.

Table 20 (Continued)

No	Reference	Addressed issues
[42]	(Rambonilaza & Neang, 2019)	Evaluation of customer preferences and potential markets on rice productions regarding water ecosystem services in South East Asia
[43]	(Rohmah et al., 2015)	The study is to understand the situation and activities of the supply chain involving organic rice, discover risks, prioritize risks in the organic rice supply chain in MUTOS Seloliman.
[44]	(Behzadi et al., 2018)	Quantitative paradigms for risk management in the agribusiness supply chain: identification of resilient and robust by using mathematical models.
[45]	(Sharma et al., 2013)	Handling on practical issues of the rice supply chain in India: cooperation, inventory control, demand management, and handle with issues-system and redesigning.
[46]	(Cheraghalipour et al., 2019)	Using bi-level programming and evolutionary algorithms to design and solve for a rice supply chain in Iran.
[47]	(Dewi et al., 2015)	Identification of supply chain performance of horticulture in Mojokerto.
[48]	(Germšek, 2014)	Challenges and trends related to logistics and supply chain in the field of agriculture.
[49]	(Septifani et al., 2019)	To discover the priority level of risk and strategies for risk mitigation involving the supply chain of rice seed in Indonesia: using fuzzy-FMEA and fuzzy-AHP.
[50]	(Hunsberger et al., 2018)	The linkage between Cambodia land conflicts and climate fluctuation management in the Greater Aural region of Cambodia. The linkage includes biofuel demand and building of irrigation infrastructure.
[51]	(Nguyen et al., 2018)	Evaluating interrelationship between efficiency of agricultural production and extraction of forest in Cambodia: adopted stochastic frontier analysis.

Table 20 (Continued)

No	Reference	Addressed issues
[52]	(Nguyen et al., 2019)	Multiple shocks (droughts, floods, livestock diseases) and strategies to the shocks in the countryside of Cambodia
[53]	(Thanawong et al., 2014)	Assessing eco-efficiency of paddy field in Northeastern Thailand. It includes societal dimension, environmental dimension, farmers' profitability, and development of irrigation infrastructure.
[54]	(Giannakis & Papadopoulos, 2016)	Exploring an operational perspective of sustainable supply chain management (environmental, social, and economic) by studying it as a risk management process.
[55]	(Nto et al., 2014)	Assessment of risk management practices by examining farmers' profile, identifying risks, ranking the degree of influence, and evaluating risk management practices in rice production in Nigeria
[56]	(Pakdeenarong & Hengsadeekul, 2020)	To know supply chain risk management (SCRM) in organic rice in Thailand, such as risk identification, priority, and mitigation.
[57]	(Yeboah et al., 2014)	Identifying risks (prioritizing likelihood and severity) in the agricultural supply chain in GhanA
[58]	(Khoo et al., 2019)	Evaluating the sustainability in life cycle assessment (LCA), external supply chain risks, and Geographical Information System (GIS).
[59]	(Thongrattana, 2012)	Analyzing the effects of uncertainty factors on performance and management practices in the rice supply chain. Moreover, analyzing the effects of management practices on performance in the rice supply chain in Thailand.

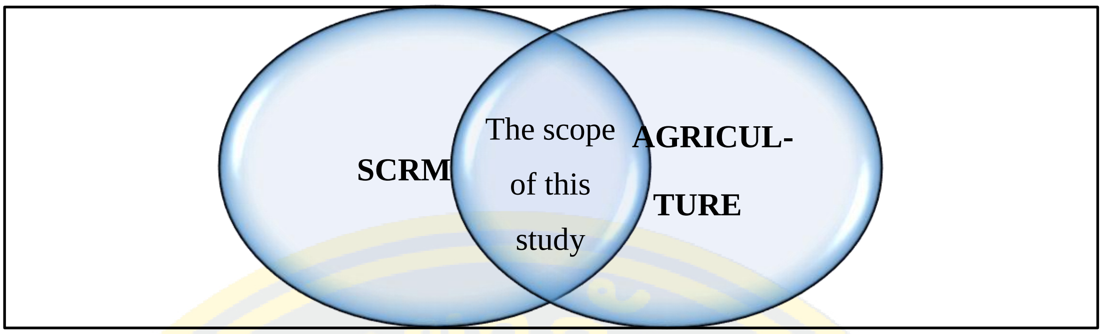


Figure 24 Venn diagram of research gap in reviewed papers

According to literature reviews, the research gap (Figure 24) is:

1. Since few studies have ever been conducted in that location, given this opportunity, the researcher believes that it is also essential to study the risk management and strategies in the rice supply chain that play a crucial role.

2. It is missing or insufficient information about the risk analysis of the rice supply chain in Cambodia.

Therefore, the importance of this research includes providing the knowledge connected with an enduring common practice, applying theories, making the generalizations, applying advanced methodology, evaluating a specific practice in Cambodia, and exploring new innovations for rice supply chain management.

Structural equation modeling and method application

1. Structural equation modeling (SEM)

SEM subsumes univariate and multivariate analysis. Analyzing of univariate or analyzing of one variable includes hypothesis-testing for small samples (t-test), analysis of variance (F-test or ANOVA), regression (linear regression and correlation), and multiple regression (multiple regression and correlation) (Grimm et al., 2016; Lowry & Gaskin, 2014). The multivariate analysis includes path analysis, confirmatory factor analysis, and others. (Grimm et al., 2016). Key structural equation modeling concepts (SEM) are related to 1G statistical approaches and 2G statistical approaches. Approaches of first-generation (1G) consist of regressions, t-test, ANOVA, and correlations which are insufficient capability for modeling. On the other hand, approaches of the second-generation (2G)-including PLS or

CB-SEM, provide flexibility, extension, capabilities, and scalability for causal modeling. Moreover, approaches of second-generation (2G) do not invalidate the demand of 1G approaches. But the key point of 2G techniques is that they are better for complicated causal modeling in scientific communication and social research of behavior (Lowry & Gaskin, 2014). SEM is used to analyze multivariate data, and one of many requirements of applying SEM is the interval scale (Mondiana et al., 2018). Chen et al. (2013) used a 7-point Likert scale between "strongly disagree" and "strongly agree" to assess the items. The primary classification of structural equation modeling (Table 21, Table 22, and Figure 25) includes as following:

Table 21 Univariate analysis and inferential statistics

No	Univariate analysis and inferential statistics	References
[1]	Hypothesis tests (t-test)	(Heumann & Schomaker, 2016; Meyers et al., 2013; Sheth & Sheth, 2019)
[2]	Analysis of variance (F-test or ANOVA), ANCOVA, MANOVA, MANCOVA	(Ali & Hossain, 2016; Bruce & Bruce, 2017; Delaney & Maxwell, 1981; Huang, 2020; Jamieson, 2004; Kass et al., 2014; Sahu, 2013; Taylor, n.d.; Woodrow, 2014; Zumbo, 2014)
[3]	Linear regression and correlation	(Bruce & Bruce, 2017; David, 2017; Mertens et al., 2017; Salkind, 2017; Stockemer, 2019)
[4]	Multiple regression analysis (MRA) and correlation	(David, 2017; Rich et al., 2018)

Table 22 Applying SEM in scientific research

No	SEM Methodology	Addressed issues
[1]	Path analysis-causal modeling (Hill et al., 2006, p. 566)	The researcher analyzed and hypothesized causal relationships by adopting structural equation modeling (SEM) to understand anthropogenic effects and the effects of agriculture on stream eco-system conditions and the environment (Chará-Serna et al., 2015).
[2]	CFA-confirmatory factor analysis (Hill et al., 2006, p. 566)	CFA is applied to restructure intervention strategies to develop paddy production in Iran. That study demonstrates the test of the model fitness by actual data from the research area and assessment of public policy intervention (Shadfar & Malekmohammadi, 2013).
[3]	Second-order factor analysis (Hill et al., 2006, p. 566)	The researcher assessed farmers' points of view on the consequences of the drought: by using second-order factor analysis (Hosseini et al., 2018).
[4]	Regression models (Hill et al., 2006, p. 566)	The author used Multiple Linear Regression to analyze agricultural data to be optimum crop production (Majumdar et al., 2017).
[5]	Covariance Based Structural Equation Modeling (CB-SEM) (Hill et al., 2006, p. 566)	The author illustrates the disadvantages and benefits of CB-SEM related to the family business (Astrachan et al., 2014).
[6]	Correlation structure models (Hill et al., 2006, p. 566)	The researcher applied the correlation matrix in the research: understanding farmers' perspectives and behavior on land fragmentation in Ethiopia (Gessesse et al., 2019).

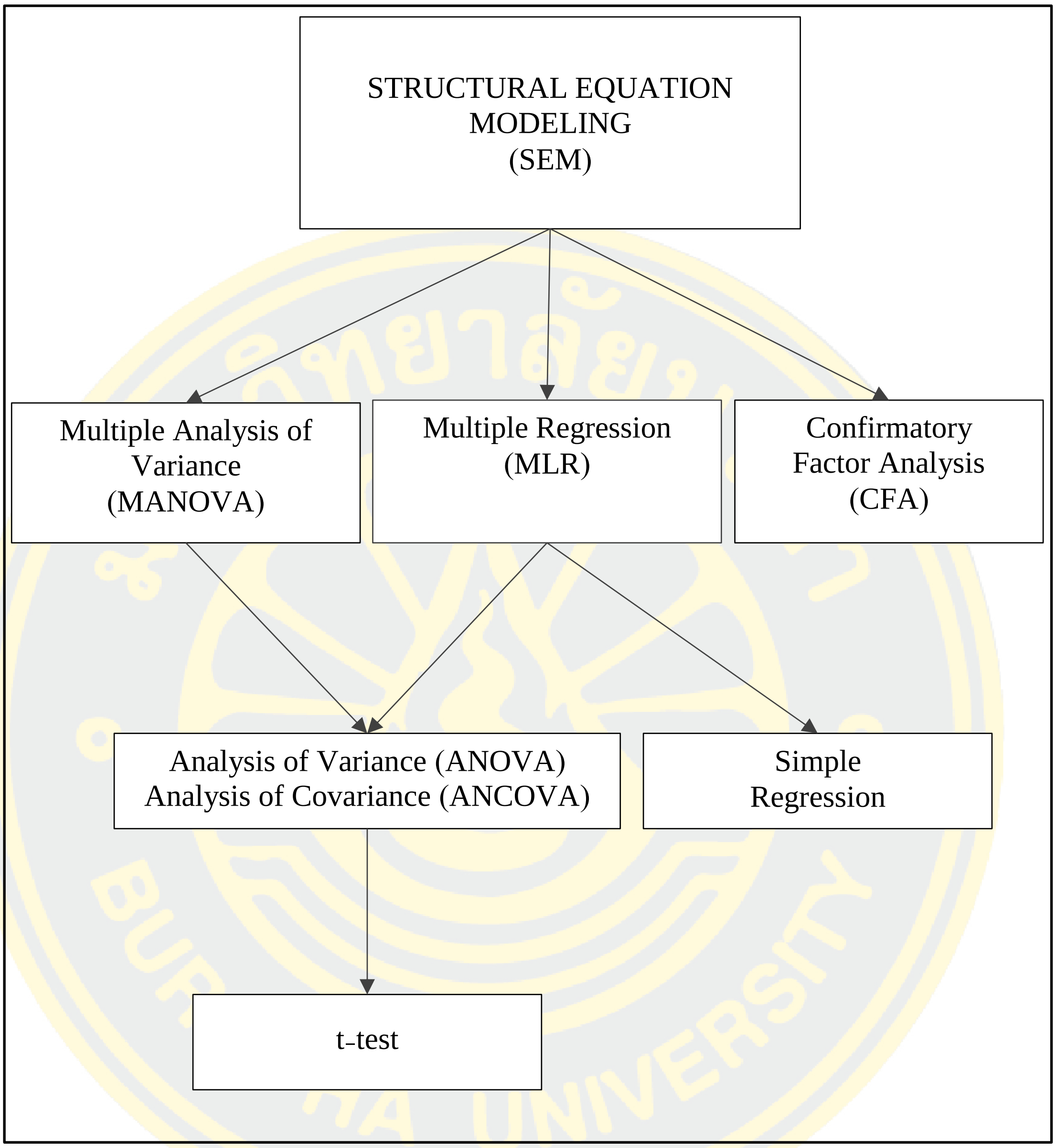
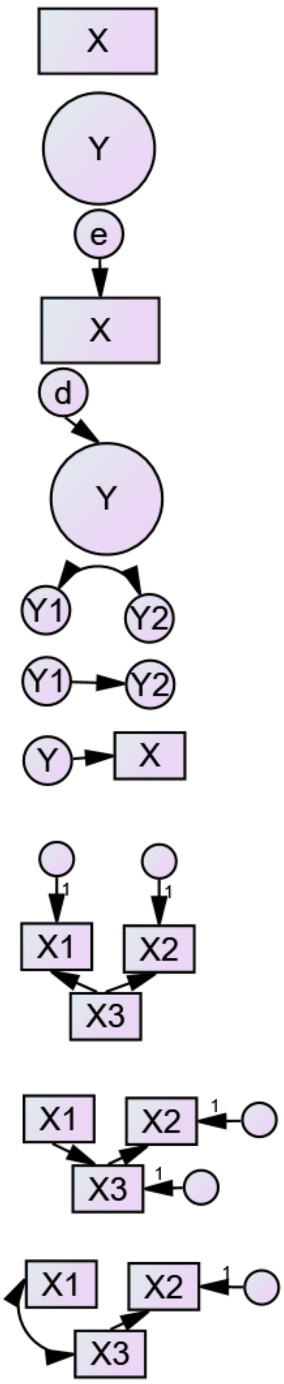


Figure 25 Relationship of statistical procedure

Sources: Keith (2019)

Figure 26 shows the types of variables in structural equation modeling (SEM).



Observed Variable/ Manifest Variable “X”

Un-observed Variable/ Latent Variable “Y”

Measurement error with Observed Variable “X”

Residual error in the prediction of Latent Variable “Y”

Correlation or covariance between “Y1” and “Y2”

Path coefficient for regression (direct relationship)

Path coefficient for regression of “X” onto “Y” (direct relationship)

Spurious relationship-both have a common cause

Indirect relationship-both are related by an intervening "X3"

Joint effect-difference between “Indirect” and “Spurious”

Figure 26 Types of variables in SEM

Sources: Coromina (2014); Von Oertzen et al., (2015) Multivariate analysis is used for estimating the relationship statistically among more than two variables simultaneously (Rich et al., 2018). The multivariate analysis includes path analysis, confirmatory factor analysis, SEM, others. (Grimm et al., 2016).

1.1 Path analysis

The simple path analysis is employed to analyze theoretical models that examine the directional relationships between many manifest variables (Figure 27) (O'Rourke & Hatcher, 2013; StataCorp, 2013). Again, it does not deal with directional relationships between latent variables. Path analysis is an extension or more complex form of multiple regression statistical analysis (O'Rourke & Hatcher, 2013). It is the oldest member of the SEM family, yet it is not obsolete (Kline, 2015). Path analysis has two advantages over multiple regression. First, it is a multivariate approach-the processing possibility for several dependent variables simultaneously. Second, the possibility of decomposing the total effect of one variable to another (direct and indirect effects) is another main advantage (Gana & Broc, 2019).

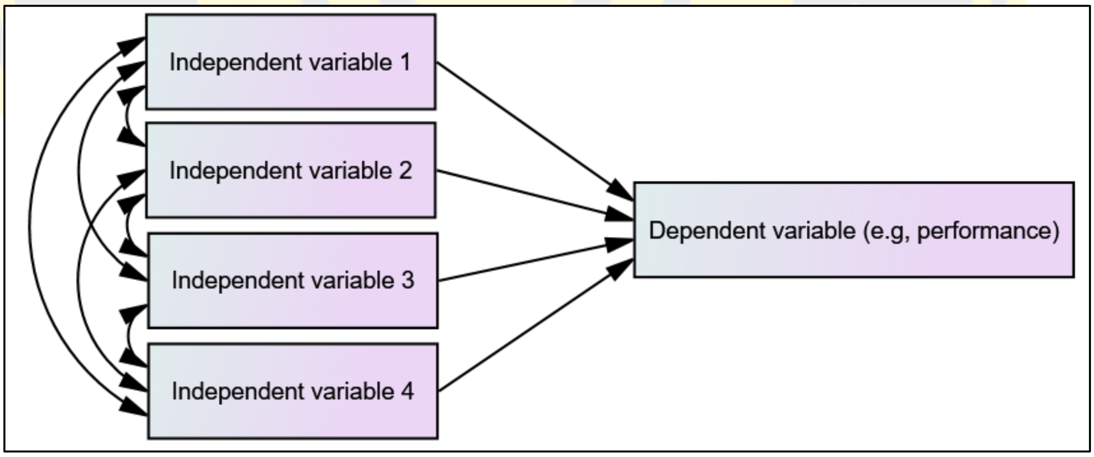


Figure 27 Example of simple path diagram
Sources: O'Rourke & Hatcher (2013)

This model, as demonstrated below, is employed in sociology under the name of path analysis (Figure 28). The dependent variables are ordered in a pattern (recursive system). In this relationship, Y1, Y2, and Y3 are dependent variables.

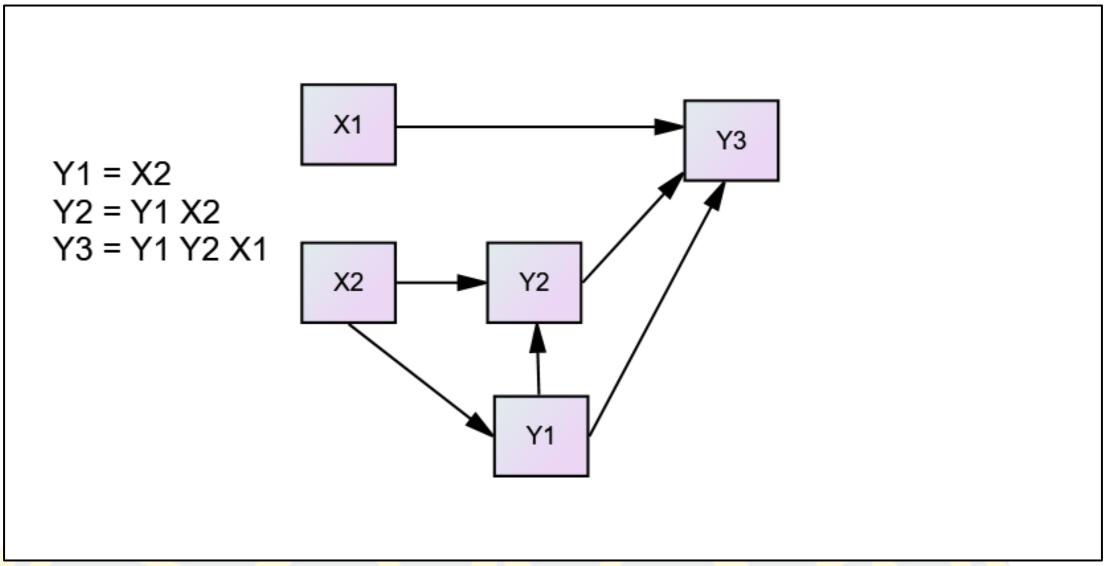


Figure 28 Example of path analysis

Sources: Duncan (1975) as cited in Jöreskog et al., (2016)

The relationships can be written as:

Y1 = X2

Y2 = Y1 X2

Y3 = Y1 Y2 X1

Alternately, the relationships can be written as:

Y1 = 0*X1 X2

Y2 = Y1 0*X1 X2

Y3 = Y1 Y2 X10*X2 (Duncan, 1975, as cited in Jöreskog et al., 2016)

1.2 CFA models

CFA, confirmatory factor analysis, is a way of studying in detail related to measurement models. “The measurement models” is a synonym for CFA models (StataCorp, 2013). CFA consists of five stages-specifying the model, identifying, estimating, testing fit, and re-specifying (Kelloway, 2015). CFA has at least two main advantages over path analysis. First, it deals with the relationships between unobserved variables to assess the convergent and discriminant validity (Jöreskog et al., 2016; O’Rourke & Hatcher, 2013). Second, it enables measuring the error of unobserved variables (O’Rourke & Hatcher, 2013).

The below figure (Figure 29) illustrates the hypothesis of a hierarchical factor solution (e.g., second-order or higher-order CFA model). For example, “Factor 1”, “Factor 2”, “Factor 3”, and “Factor 4” are four first-order or lower-order factors that are influenced by a second-order or higher-order factor. It is a factor of factors.

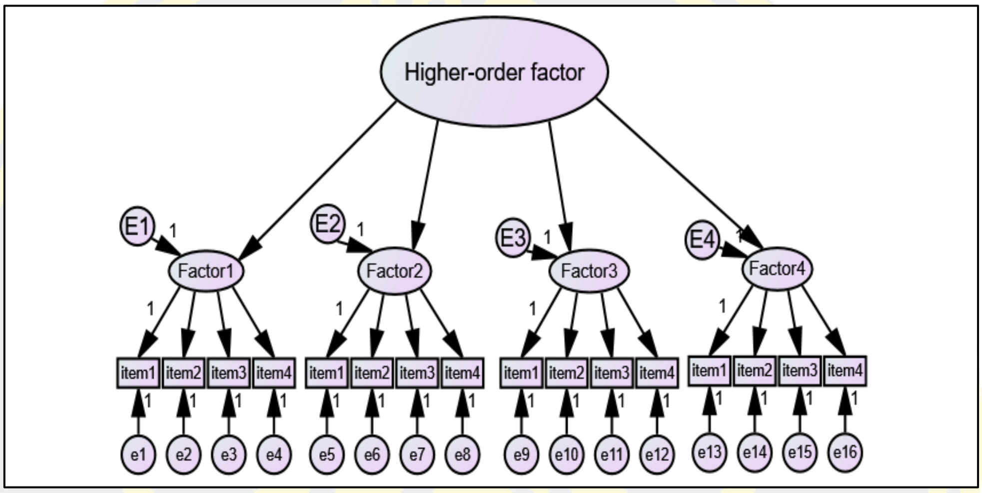


Figure 29 Example of CFA Model

Sources: Gana and Broc (2019)

1.3 Structural equation model

If there are structural relationships by imposing on unobserved variables, they are called SEM (Figure 30 and 31). However, if there are only associations among the un-observed variables, they are called only CFA models (Cheung, 2015). The structural equation model (SEM) is a statistical tool to analyze the relationship between latent variables. Latent variables refer to latent factors that the researcher cannot observe directly. Latent variables are estimated observed variables. The researcher measures observed variables (manifest variables) (Jason & Glenwick, 2016).

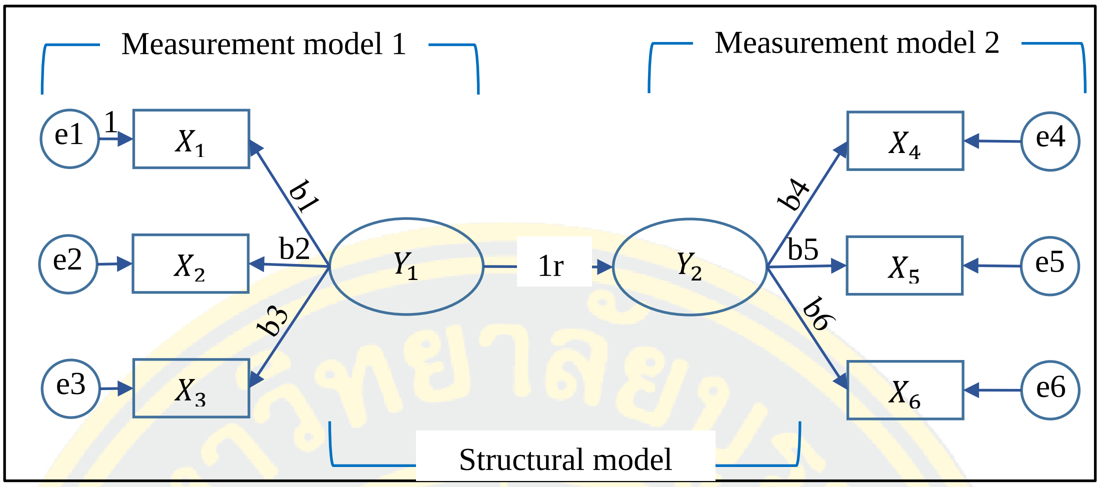


Figure 30 Simplified representation of the structural equation modeling

Sources: Xiong et al., (2015)

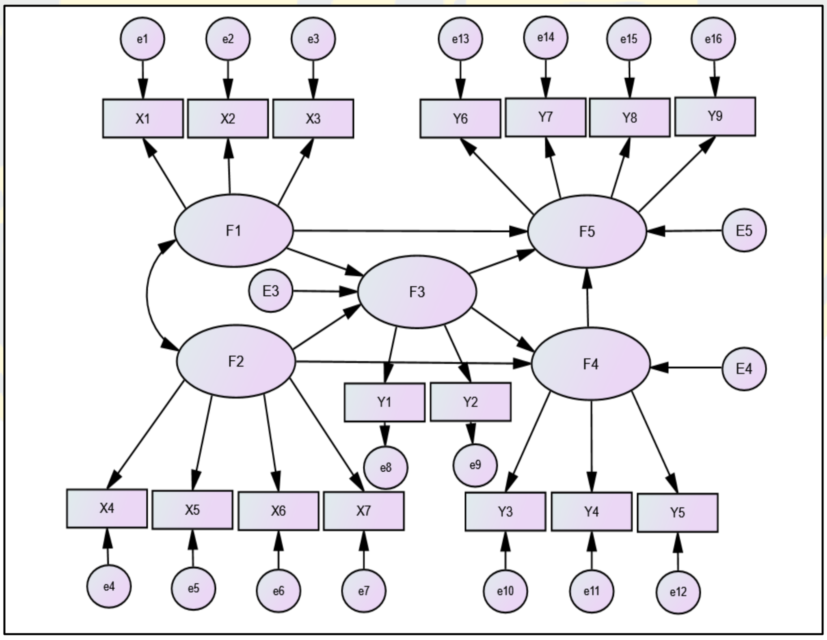


Figure 31 Standard SEM diagram

Sources: Gana and Broc (2019)

Figure 32 shows the flow chart in the structural equation model (SEM).

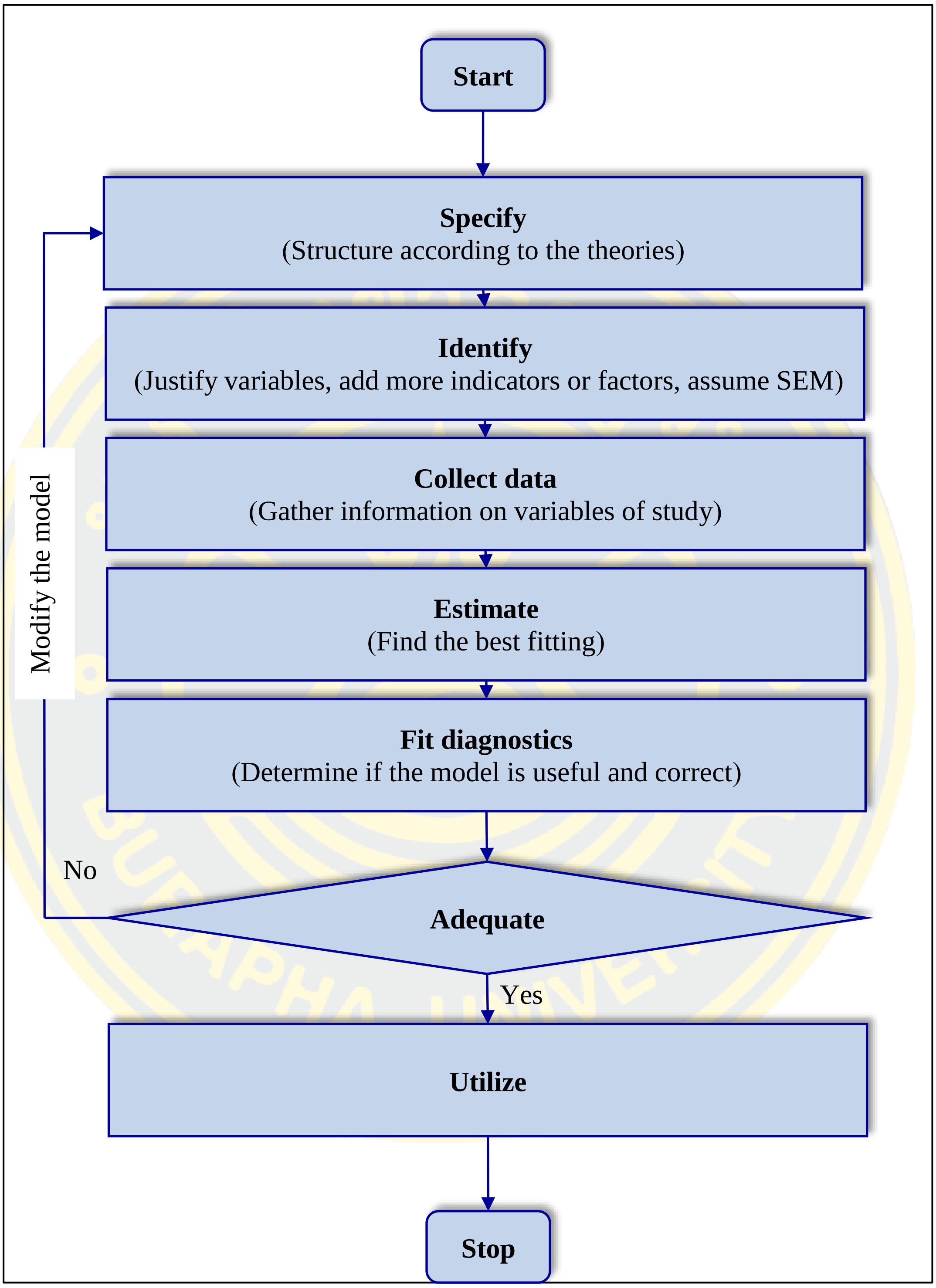


Figure 32. Flow chart in SEM

Sources: Coromina (2014)

- PLS-SEM

PLS Analysis stands for Partial Least Squares Analysis; its objective is to prove path analysis (Figure 33) (Haenlein & Kaplan, 2004; Piriyakul, 2011, as cited in Muangpan, 2015).

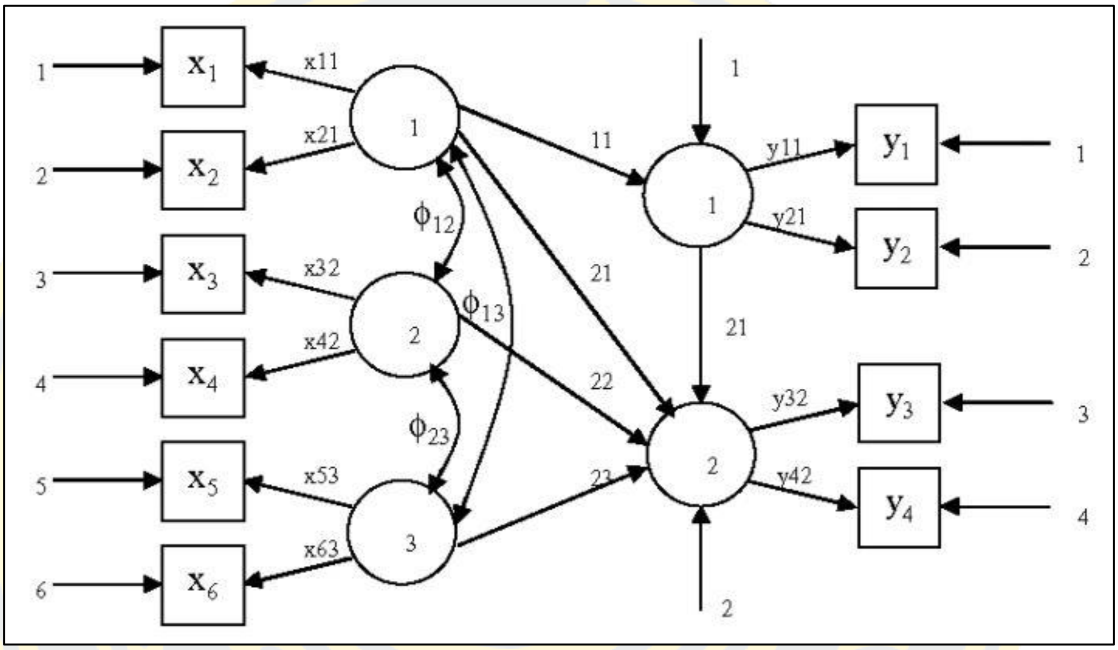


Figure 33 PLS-SEM

Sources: Haenlein and Kaplan (2004)

- Equation (1): $x = \Lambda_x \xi + \delta$

$x_1 = \lambda_{x11}\xi_1 + \delta_1$

$x_2 = \lambda_{x21}\xi_2 + \delta_2$

$x_3 = \lambda_{x32}\xi_3 + \delta_3$

$x_4 = \lambda_{x42}\xi_4 + \delta_4$

$x_5 = \lambda_{x53}\xi_5 + \delta_5$

$x_6 = \lambda_{x63}\xi_6 + \delta_6$

- Equation (2): $y = \Lambda_y \eta + \varepsilon$

$y_1 = \lambda_{y11}\eta_1 + \varepsilon_1$

$y_2 = \lambda_{y21}\eta_1 + \varepsilon_2$

$y_3 = \lambda_{y32}\eta_2 + \varepsilon_3$

$y_4 = \lambda_{y42}\eta_2 + \varepsilon_4$

-Equations (3): $\eta = B\eta + \Gamma\xi + \zeta$

$\eta_1 = \gamma_{11}\xi_1 + \zeta_1$

$\eta_2 = B_{21}\eta_1 + \gamma_{21}\xi_1 + \gamma_{22}\xi_2 + \gamma_{23}\xi_3 + \zeta_2$

(Haenlein & Kaplan, 2004; Narayanan, 2012)

Note: see table "Full notation of linear structural relations (LISREL)" for a brief explanation.

- LISREL-SEM and Notation

LISREL stands for linear structural relations for synthesizing and expanding decades of prior work on path analysis and CFA into a highly generalizable SEM (Figure 34 and Table 23) (Newsom, 2015). Sometimes the synonym of LISREL is covariance-based SEM; its objective is to expand the possible structure and the analysis (Haenlein & Kaplan, 2004; Piriyakul, 2011, as cited in Muangpan, 2015).

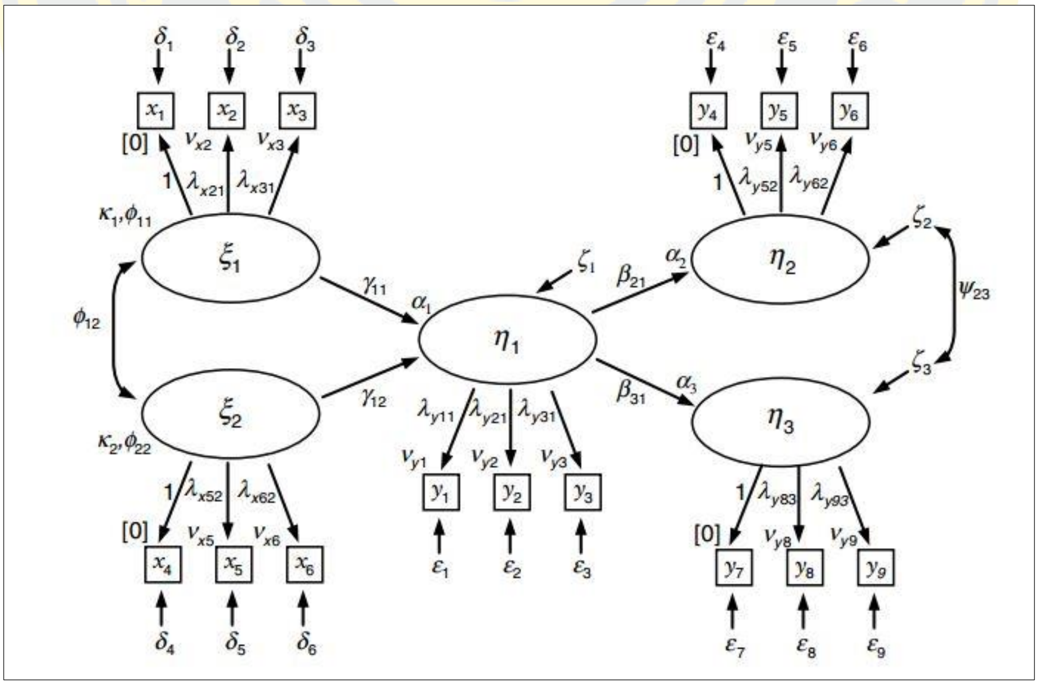


Figure 34 Example of SEM and notation

Sources: Newsom (2015)

- An equation of relationship between observed variable and latent variables:

$$y_j = \nu_j + \lambda_{jk}\eta_k + \varepsilon_j$$

Where:

k = an individual case of un-observed variables

K = total un-observed variables

j = an individual case of observed variables

J = total observed variables

jk = jth observed variable is predicted by kth latent variable

y_j = indicators of endogenous variables with subscript j

ν_j (Nu) = Measurement intercepts with subscript j

λ_{jk}(lambda) = factor loadings of y_j on factor η_k

η_k (Eta) = un-observed variables with subscript k

ε_j (epsilon) = measurement residual (or error term) subscript j

(Newsom, 2015)

Table 23 Full notation of linear structural relations (LISREL)

Exogenous				
No	**Exogenous parameter**	**English spelling**	**Exogenous matrix**	**Brief explanation**
1	λ_x	Lambda-x	Λ_x	Factor loadings for loadings on exogenous un-observed variables
2	φ	Phi	Φ	Variances and co-variances of exogenous un-observed variables, $Var(\xi)$ & $Cov(\xi,\xi)$

Table 23 (Continued)

Exogenous				
No	**Exogenous parameter**	**English spelling**	**Exogenous matrix**	**Brief explanation**
3	γ	Gamma	Γ	Causal path, endogenous (dependent) predicted by exogenous
4	θ_δ	Theta-delta	Θ_δ	Measurement residual variances of "x" variables
5	δ	Delta	δ	Variances and co-variances of residual, variances are elements of theta-delta matrix, $Var(\delta) = \theta_\delta$
6	ξ	Ksi	ξ	Exogenous un-observed variables
7	κ	Kappa	κ	Exogenous un-observed variable mean
8	ν_x	Nu-x	ν_x	Measurement intercepts for "x"
9	ν_y	Nu-y	ν_y	Measurement intercepts for "y"

Sources: Newsom (2015)

1.4 SEM Software

There are many application software for SEM, which allow for analyzing complex relationships between variables-manifest variables and latent variables (Table 24). For instance, El-Sheikh et al. (2017) studied software packages such as AMOS, LISREL, R (Sem, OpenMx, Lavaan) for SEM by comparative study, and the researcher concluded that AMOS, LISREL, and Lavaan produce very similar or the same if the same method is applied. The same study demonstrates that the option of utilizing depends on users' needs and easiness to handle. Wild (2017) illustrates the advantages, disadvantages, and information of SEM software packages, including Mplus, R program, SAS, EQS, LISREL, AMOS, and others.

There are many packages of software for structural equation modeling (SEM). The following example for consideration:

1. IBM SPSS Amos (Analysis of Moment Structures) (Arbuckle, 2019)
2. SAS (O'Rourke & Hatcher, 2013)
3. R program-R package sem (Narayanan, 2012)
4. R program-R package lavaan (Gana & Broc, 2019)
5. R program-R package OpenMx (Narayanan, 2012)
6. Mplus (Kelloway, 2015)
7. LISREL (Jöreskog et al., 2016)
8. EQS (Kline, 2015)

Table 24 Fit indices of some SEM software for single-group analysis

Model-fit indices	**IBM SPSS Amos**	**SAS PROC CALIS**	**R package sem**	**R package lavaan**	**R package OpenMx**	**Mplus**	**LISREL**	**EQS**
Overall-fit indices								
Model x^2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline x^2	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Minimum fit function value	Yes	Yes	No	No	No	No	Yes	Yes
Incremental fit indices								
Normed fit index (NFI or Delta1)	Yes	Yes	Yes	No	No	No	Yes	Yes
Non-normed fit index (NNFI) or Tucker Lewis index (TLI)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Incremental fit index (IFI or Delta2)	Yes	Yes	No	No	No	No	Yes	Yes
Comparative fit index (CFI)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 24 (Continued)

Model-fit indices	IBM SPSS Amos	SAS PROC CALIS	R package sem	R package lavaan	R package OpenMx	Mplus	LISREL	EQS
Information theory based								
Akaike information criterion (AIC)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Consistent AIC (CAIC)	Yes	Yes	Yes	No	No	No	Yes	Yes
Bayesian information criterion (BIC) or Schwarz's Bayesian criterion (SBC)	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Goodness-of-fit index (GFI)	Yes	Yes	Yes	No	No	No	Yes	Yes
Root mean square residual (RMSR)	Yes	Yes	No	No	No	No	Yes	Yes
Standardized root mean square residual (SRMR)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Hoelter's N (0.05)	Yes	Yes	No	No	No	No	Yes	No
Root mean square error of approximation (RMSEA)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Parsimony fit indices								
Adjusted GFI (AGFI)	Yes	Yes	Yes	No	No	No	Yes	Yes
Parsimony GFI (PGFI)	Yes	Yes	No	No	No	No	Yes	No

Sources: Narayanan (2012)

2. Mixed method

The worldviews, quantitative designs, qualitative designs, or mixed designs contribute to the research approach (Table 25) (Creswell, 2014).

Table 25 Comparison of research designs

Quantitative Designs	Qualitative Designs	Mixed Designs
- Testing the theories by analyzing the variable relationship	- Investigating meaning and understanding of human and social issues	- Involving not only quantitative data but also qualitative data for framework and assumptions.
- Design of experiments - Design of none-experiments	- Narrative research study - Phenomenology research - Grounded theory research - Ethnographic research - Case study	- Convergent designs - Explanatory designs - Exploratory designs - Transformative designs
- Methods of pre-determined [1]	- Methods of emerging [2]	- Both [1] and [2]
- Instrumentation interview questions	- Open-ended question	- Both closed-ended and open-ended questions
- Data: census, observation, thoughts, performance	- Data: Observation, document, interview, and using both sound and pictures (audio-visual information)	- Both quantitative data and qualitative data on all possibilities
- Using statistical tools	- Using text, figure, or image	- Not only utilizing statistical tools but also text
- Result interpretation from statistical analysis	- Covering interpretation of databases	- Interpretation of text and patterns

Sources: Creswell (2014)

The mixed-method research is well-liked in behavioral and social science; the scientific researchers collect data, analyze data, and interpret results by integrating qualitative data and quantitative data in the unique research to answer their research questions (Creswell, 2013). The researcher used a mixed-method for exploratory design to understand the Internet of Things (IoT) in logistics and supply chain management. The primary objective is to know motivations and concerns about the Internet of Things (IoT), identify risks and issues involving IoT technology, and discover factor effects related to IoT in logistics and supply chain management. For qualitative methodology, “Grouped Theory” is used. For quantitative methodology, structural equation modeling with partial least square is applied (Tu, 2018). According to Musau et al. (2017), mixed-method as the convergent parallel mixed method was used to understand the impact of inventory management on profit, cost, reliability, responsiveness, and flexibility in textile supply chain performance in Kenya. Crivits and Paredis (2013) designed an explanatory study for the role of sustainable food consumption. Figure 35 shows the primary mixed methods designs.

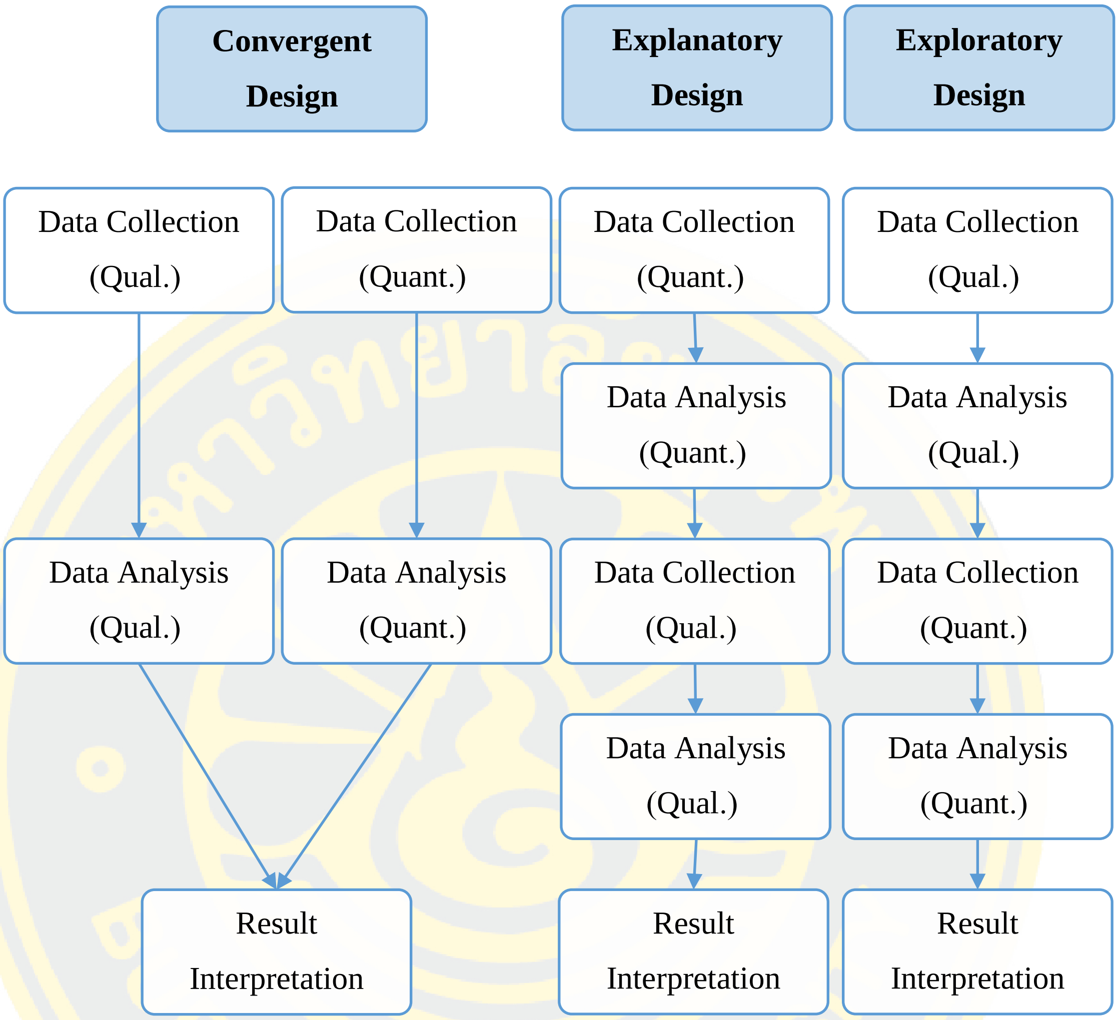


Figure 35 Primary mixed methods designs

Sources: Steinmetz-Wood et al., (2019)

Conclusion for chapter

The primary purpose of reviewing documents is most closely related to the agricultural risk factors in the rice supply chain, the effects of risk factors on rice supply chain performance, risk management strategies in the sustainable rice supply chain, model and method application. Figure 36 shows the graphical summary for the chapter.

Risk factors	Supply chain performance	Risk management strategies
• Supply Risks • Production Risks • Demand Risks • Environmental Risk	• Environmental performance • Social performance • Economic performance	• Ex-ante risk management strategies (risk mitigation, risk avoidance, risk transfer) • Ex-post risk management strategies (risk coping)

Risk model and method application:

- Descriptive and inferential statistics for data analysis, including SEM, etc.
- Mixed method

Figure 36 Graphical summary for chapter

CHAPTER 3
RESEARCH METHODOLOGY

Site selection

Battambang is the third-largest province in Cambodia behind Phnom Penh and Kandal province; it has a long tradition of farming and an advantage of being able to absorb investors (Royal Government of Cambodia, 2014b; Top & So, 2016). Furthermore, Battambang has the fifth-largest population with 987,400 people (6.5 percent) after Phnom Penh with 2,129,371 people (13.9 percent), Kandal with 1,195,547 people (7.8 percent), Prey Veng with 1,057,428 people (6.9 percent), and Siem Reap with 1,006,512 people (6.6 percent)(National Institute of Statistics-Ministry of Planning, 2019b). Moreover, Battambang has many rice mills and millers that are able to produce rice for national and international markets. These rice millers collect rice in the city and from other districts; they then name the collective branch of Battambang rice to sell locally and overseas. Besides, this province is known as being a regional business and transportation center, distributing rice and other agricultural products (Han & Lim, 2019). More importantly, rice farming is hugely popular across the Kingdom, with the top five rice producers being Prey Veng, Takeo, Battambang, Kampong Thom, and Banteay Meanchey in 2015 accounting for 50 percent of all paddy fields (BDLINK, 2017). Even though hazardous weather has affected farmers who suffer for adverse effects, Battambang province still produced rice a total of 713,747 tons of rice and was still the third-largest rice producer in the country in 2015 (Top & So, 2016). Battambang, “Cambodian Rice Basket”, is one of the largest rice-producing areas in Cambodia (Bunthan et al., 2018). These figures indicate one side of the success story of supply chain performance from the stakeholders who benefited from it; this is the primary reason for the study in this province. Indeed, the researcher chose all communes in Battambang (102 communes) for the investigation of the rice supply chain (See Figure 37 and Appendix A. relevant maps and information).

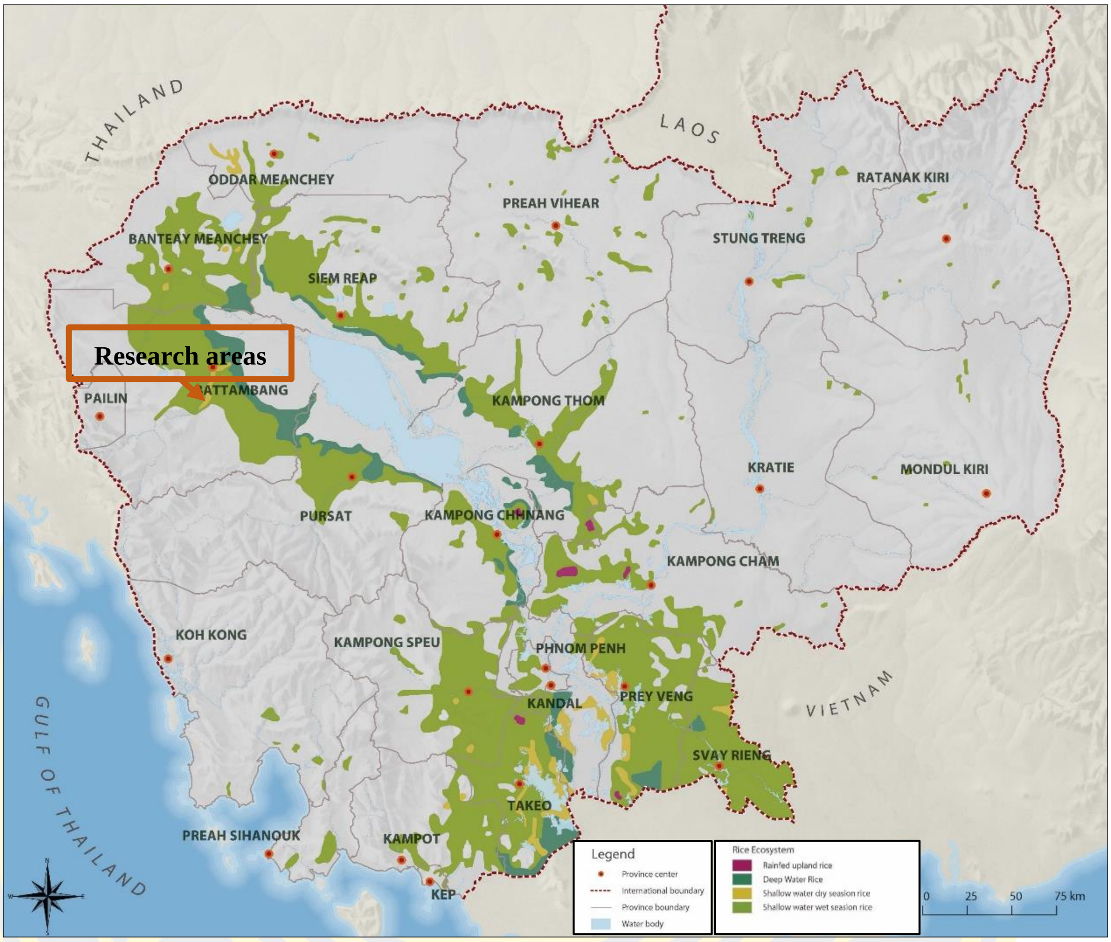


Figure 37 Research areas and rice ecosystem map for Cambodia

Sources: Open Development Cambodia (2019a)

Research design and process

This research design is comprised of a set of mixed methods applied for data collection and analysis to measure the variables stated in research problems.
This design goes along with the conceptual framework (Figure 2) to explore the set research questions.

This study on Risk Analysis of Rice Supply Chain in Cambodia (Figure 38) encompasses four steps consecutively:

Step 1. Desk-level examination and secondary-data collection for literature review-risk factors (internal and external supply chain risks), sustainable performance factors, risk management strategies, and research methods.

Step 2. Phase I: In-depth interview with experts to identify the agricultural risk factors; sampling size by using rules of thumbs (n_1 = 10 experts); sampling method by using expert sampling; and qualitative data analysis by using prioritization matrix of risk (as demonstrated in Figure 22).

Step 3. Phase II: Questionnaire survey with stakeholders to investigate risks that affect performance; sampling size by using "A-priori sample size method" (n_2 = 200 samples); sampling method by using simple random sampling; and quantitative data analysis by using structural equation modeling (SEM).

Step 4. Phase III: Risk management strategies; and quantitative data analysis using statistical tools.

Therefore, the study begins by examining the literature review, conducting in-depth interviews, analyzing qualitative data, conducting surveys, and analyzing quantitative data to make the study topic scientifically clear and robust.

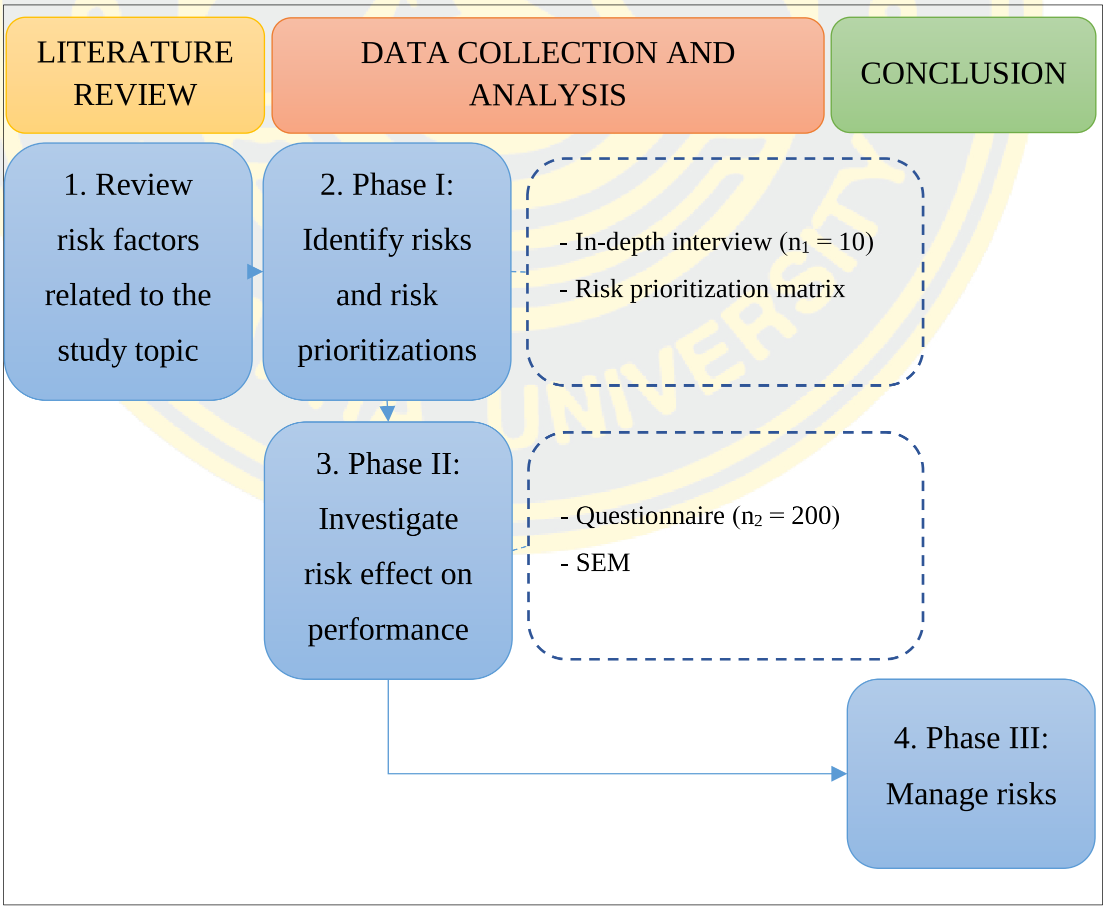


Figure 38 Research design on risk analysis of rice supply chain

The research process (Figure 39) was designed based on the objectives of the study, with 11 steps as follows:

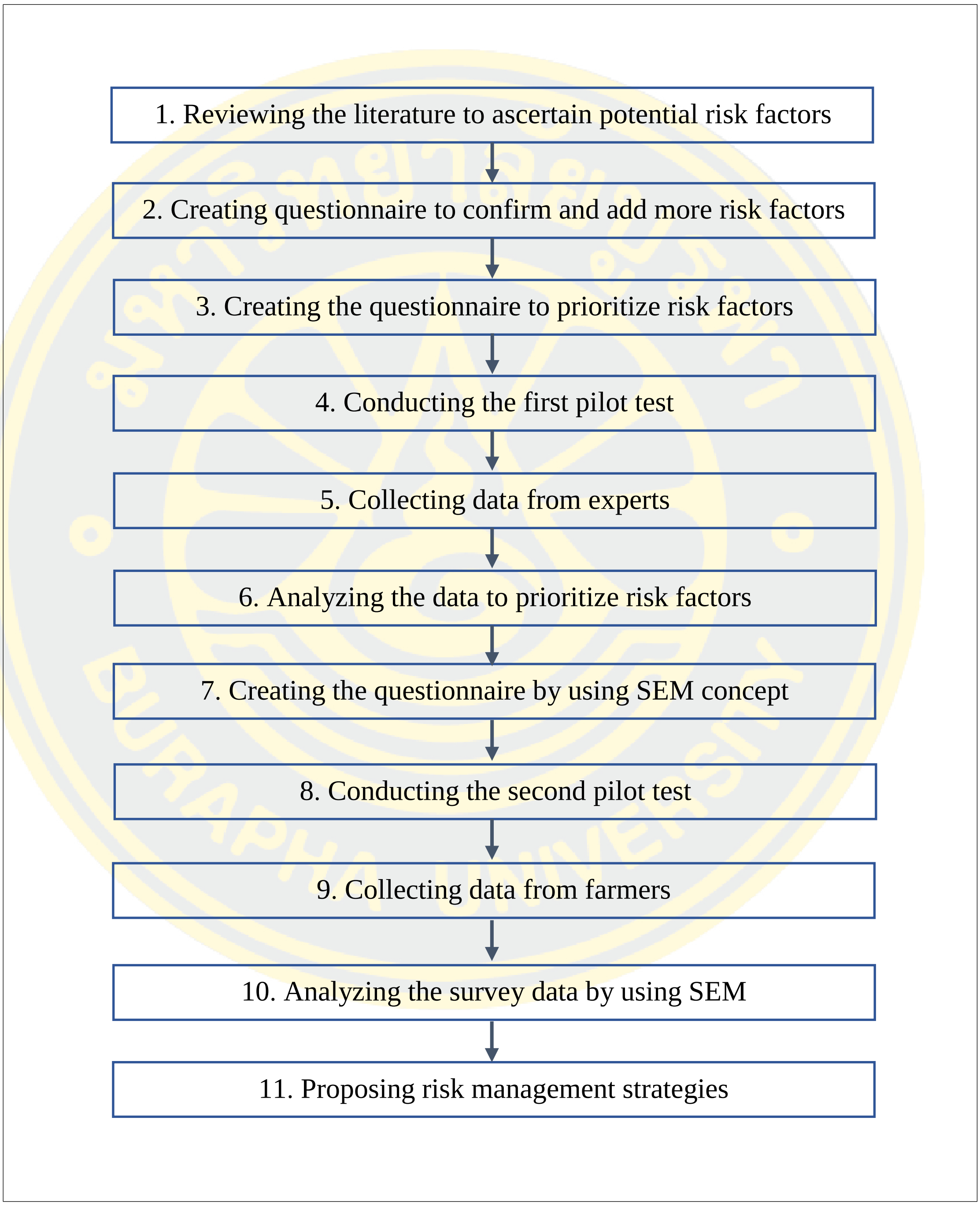


Figure 39 Flow chart of study on risk analysis of rice supply chain

Step 1: The researcher reviewed the literature to ascertain potential risk factors.

Step 2: The researcher created the questionnaire used to interview some samples to confirm factors and add more risk factors that farmers face.

Step 3: The researcher created the questionnaire to be used to prioritize risk factors.

Step 4: The researcher tried out 20 samples (the first pilot test).

Step 5: The researcher collected the data by conducting in-depth interviews one by one with experts (n1=10 experts).

Step 6: The researcher analyzed the data to prioritize risk factors (risk assessment matrix).

Step 7: The researcher created the questionnaire by using the SEM concept.

Step 8: The researcher tried out 30 samples (the second pilot test).

Step 9: The researcher collected the data by surveying farmers (n_2 = 200 samples) (Table 26).

Step 10: The researcher analyzed the survey data by using SEM. The researcher tried to find the best fitting and adequacy of SEM.

Step 11: The researcher proposed risk management strategies.

Sample size and sampling methods

1. Sample size

1.1 Sample size for qualitative design

Decision-making on the budget to invest and time frame necessitate for researchers. Researchers analyze meticulously to minimize bias and to saturate the qualitative study. Saturation refers to no new related data being forthcoming, although researchers interview more people in the study (Galvin, 2015). No success in reaching saturation of data negatively affects the validity of the study. To achieve saturation is to interview the experts, make a focus group, and create a saturation grid (Fusch & Ness, 2015). Furthermore, the sample required for qualitative design depends on the type of research; there are many types of research for qualitative studies, such as 1) ethnographic research (study about culture, business, educational and medical fields), 2) phenomenological research (study about the meaning of participant's lived experience), 3) grounded theory research (study about developing the theory), and 4) and content analysis research (applying in primary care studies) (Moser & Korstjens, 2018). Malterud et al. (2016) recommended that sample size with information power relies on the study's objectives, the particularity of the sample, the purpose of established theory, interview dialogue for weak or strong, and the strategy selection for analysis.

This study used diverse rules of thumb to pick up the sample size of 10 experts for the qualitative design to achieve saturation. The advantages of diverse rules of thumbs are popular due to quick, convenient, or handy ones. According to Boddy (2016), over 30 in-depth interviews with experts should justify a sample size because it is too large for a single homogeneous society, market, or country. Karania (2017) demonstrated that the sample size for the qualitative design should be between below ten people or no more than 30 people for interviews, 3-6 groups with approximately 4 to 8 members in each for focus group discussions, from 10 to 20 people for participatory methods, and five-fifteen people for observational methods. Owie (2019) interviewed face-to-face and used non-probability sampling (purposive method) that determined sample size (practitioners with professional experience) to represent a population in a topic of sustainable supply chain management in the manufacturing industry for the qualitative design. Reeves (2019) conducted qualitative research to study reverse logistics management involving controlling cost via risk mitigation by applying a purposive for choosing sample size (n = five managers in the supply chain).

There are three requirements for experts in this research:

- Senior rice farmers
- Experience that is equal to or more than five years
- Holding a minimum of a Master’s Degree in a related field.

1.2 Sample size for quantitative design

Many researchers make suggestions about choosing sample size by analyzing and examining with great care (Hair et al., 2013). Furthermore, decision-making on sample size with accepted precision is crucial in designing scientific research. Indeed, a sample size that is too small might not get the desired output, while a too-large sample size might be a complication of research related to expenditure or costs and inflexibility (Martínez-Mesa et al., 2014).

Calculating sample size to meet requirements for SEM is a challenge. Despite this, diverse rules of thumb are popular due to quick, convenient, or handy ones (Wolf et al., 2013). Many authors have illustrated the rule of thumb for sample sizes, such as at least 100 or 200 samples (Boomsma, 1982, 1985 as cited in Wolf et al., 2013), the size of 5 or 10 for each estimated parameter as demonstrated by Bentler & Chou (1987) as cited in Wolf et al. (2013) and Bollen (1989) as cited in Wolf et al. (2013), the size of 10 for each variable (Nunnally, 1967 as cited in Wolf et al., 2013). Additionally, the sample size from 200 to 500 usually is adequate, but it requires a sample size between 400 and 800 for non-normality (Coromina, 2014).

This research employed "A-priori Sample Size Calculator for Structural Equation Models" to find 200 Cambodian farmers (the sample size) to achieve saturation in the quantitative methodology. This is because it is a reliable statistics tool (adequate power in SEM) and is widely used in similar research studies. Many researchers (Alsulami, 2014; de Vos, 2015; Jayarathna & Wickramasinghe, 2019; Jensuttiwetchakul, 2015; Lee, 2019, 2020; Petitt, 2019; Tefera, 2020) applied formulas for their studies.

According to Soper (2020a, 2020b), computing the sample size for SEM requires expected effect size, statistical power, the number of observed and unobserved variables, and p-value. Minimum effect size (δ) is used to detect with sample and model, and it is the smallest correlation among unobserved variables. Large effects are easier to detect than small effects as they need less information to be collected (Christopher, 2015). According to Cohen (1988) as cited in de Vos (2015), anticipated effect sizes 0.1, 0.3, and 0.5 are considered small, medium, and large, respectively. Soper (2020a, 2020b) recommended that statistical power is $\geq$0.8 (desired level) and p-value is $\leq$0.05 (for claiming statistical significance). The statistical power (the chance of accepting the H_1-alternative hypothesis when it is true) is .80 for this research, and the p-value (the chance of rejecting the H_0-null hypothesis when it is true) is .05 for this study, which criteria are the same as Tefera (2020) and Jensuttiwetchakul (2015). Also, Soper's calculator is available at:

- https://www.danielsoper.com/statcalc/calculator.aspx?id=89 or

- https://www.analyticscalculators.com/calculator.aspx?id=89

(Soper, 2020a, 2020b)

Table 26 Necessary parameter to calculate sample size for this research

A-priori Sample Size Calculator for SEM	
Parameter	**Values**
Expected effect size:	0.30
Statistical power:	0.80
Number of unobserved variables:	9.00
Number of observed variables:	27.0
p-value:	0.05
Therefore, sample size (quantitative) is 200 Cambodian farmers	

(Soper, 2020a, 2020b)

2. Sampling method

2.1 Sampling method for qualitative design

The researcher employed an expert sampling method to choose each expert for in-depth interviews as part of a qualitative design. The expert sampling method, i.e. the sub-type of purposive sampling, is most suitable for determining experts in this field. This sampling technique is significant because it is considered the best method to elicit the perspective of rice-farming specialists with a high level of knowledge and experience in a related field.

2.2 Sampling method for quantitative design

For the quantitative design, the researcher uses simple random sampling, namely a probability sampling technique, for this study. The advantages of such simple random sample method are the accuracy of representation, the fact that there is no need to divide the population into sub-categories, and an equal chance of selection (Etikan & Babatope, 2019).

The researcher uses paper-based questionnaires and pencil or pen recording to get the data from the sample. The researcher makes the enumeration maps-delineate separately using hand-sketched area plans across the Battambang Province to survey farmers.

Reviewing and applying the paradigm

The research articles, theory, and reliable documents are reviewed for a qualitative paradigm, a core approach in the rice supply chain. This study employs pragmatism for this scientific study. Creswell (2014) demonstrated that pragmatism (an approach that investigates the truth in contexts and others) was applied successfully in mixed methods. This study is about multiple methods. The qualitative method is one way to explore risks, as reflected in the research question: what are the agricultural risk factors in the rice supply chain?

This study carries out a thorough review of structural equation modeling and statistical tools within this field. Furthermore, the structural equation modeling (SEM)-mathematical model is employed mainly for this scientific study.

Synthesizing the variables and questionnaire design

Synthesizing and finalizing the variables to a coherent whole for the questionnaire by avoiding ambiguous shaky questions or avoiding biased questions is the researcher's most important. The researcher explains the research questionnaires (see Appendix C. Research Questionnaire; Table 27, 28, 29, and 30) as follows:

1. Research questionnaire for risk identification

Part 1: Respondents' profile using the checklist, which contains sex, marital status, age, educational level, and professional experience.

Part 2: Risk identification with open-ended question.

Part 3: Other recommendations and suggestions.

2. Research questionnaire for risk prioritization

Part 1: Respondents' profile using the checklist, which contains sex, marital status, age, educational level, the position of respondent, and professional experience.

Part 2: Risk prioritization with a five-level rating scale (vulnerable to risks and risk prioritization). Every question in the research questionnaire has dualresponse or two-situation column answer that illustrates the risk prioritization in the Cambodian rice supply chain. Each rating scale was considered as follows:

- Likelihood of occurrence

5 = “strongly agree” refers to the reality that strongly suitable to the likelihood of occurrence

4 = “agree” refers to the reality that very suitable to the likelihood of occurrence

3 = “neutral” refers to the reality that moderately suitable to the likelihood of occurrence

2 = “disagree” refers to the reality that less suitable to the likelihood of occurrence

1 = “strongly disagree” refers to the reality that very less suitable to the likelihood of occurrence

- Severity of the effect

5 = “strongly agree” refers to the reality that strongly suitable to the severity of effect

4 = “agree” refers to the reality that very suitable to the severity of effect

3 = “neutral” refers to the reality that moderately suitable to the severity of effect

2 = “disagree” refers to the reality that less suitable to the severity of effect

1 = “strongly disagree” refers to the reality that very less suitable to the severity of effect

Table 27 Synthesizing variables for risk prioritization

Latent variables	**Observed variables**
1. Supply risks	1.1 Rising costs of raw materials (fertilizer, pesticide, high yield seeds) 1.2 Rising costs of services (transportation, labor, interest rates or/ and credit) 1.3 Lack of high yield seeds 1.4 Lack of labor 1.5 Lack of equipment and machinery

Table 27 (Continued)

Latent variables	Observed variables
2. Production risks	2.1 Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi) 2.2 Lack of financial capital 2.3 Misuse of fertilizer or/ and pesticide 2.4 Lack of agricultural know-how
3. Demand risks	3.1 Low prices of rice products 3.2 Lack of market information 3.3 Uncertainty of market demand for quantity 3.4 Uncertainty of market demand for quality or/ and food safety requirements
4. Environmental risks	4.1 Natural disasters (flood, drought) 4.2 Lack of irrigation systems 4.3 Lack or poor condition of basic infrastructure (roads, electricity) 4.4 Inadequate support from the government (lack of agricultural know-how training or/ and lack of public extension services) 4.5 Pandemic risks (Covid-19)

Part 3: Other recommendations and suggestions.

3. Research questionnaire for investigating risk effects and management strategies

Part 1: Respondents' profile using the checklist, which contains sex, marital status, age, educational level, and professional experience.

Part 2: Investigating risk factors that affect rice supply chain performance and focusing on risk management strategies, with a five-level rating scale.

Section 1 Risk factors in rice supply chain. Rating scale from 1 to 5 that most closely matches the risk factors that affect to performance of the rice supply chain in Cambodia:

5 = “strongly agree” refers to the reality that strongly suitable to the risk factors that affect performance

4 = “agree” refers to the reality that very suitable to the risk factors that affect performance

3 = “neutral” refers to the reality that moderately suitable to the risk factors that affect performance

2 = “disagree” refers to the reality that less suitable to the risk factors that affect performance

1 = “strongly disagree” refers to the reality that very less suitable to the risk factors that affect performance

Table 28 Table synthesizing variables for risk factors that affect performance

Latent variables	**Observed variables**
1. Supply risks	1.1 Rising costs of raw materials (fertilizer, pesticide, high yield seeds)
	1.2 Rising costs of services (transportation, labor, interest rates or/ and credit)
	1.3 Lack of high yield seeds
	1.4 Lack of labor
	1.5 Lack of equipment and machinery
2. Production risks	2.1 Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)
	2.2 Lack of financial capital
	2.3 Misuse of fertilizer or/ and pesticide
	2.4 Lack of agricultural know-how

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Table 28 (Continued)

Latent variables	Observed variables
3. Demand risks	3.1 Low prices of rice products 3.2 Lack of market information 3.3 Uncertainty of market demand for quantity 3.4 Uncertainty of market demand for quality or/ and food safety requirements
4. Environmental risks	4.1 Natural disasters (flood, drought) 4.2 Lack of irrigation systems 4.3 Lack or poor condition of basic infrastructure (roads, electricity) 4.4 Inadequate support from the government (lack of agricultural know-how training or/ and lack of public extension services) 4.5 Pandemic risks (Covid-19)

Section 2 Performance indicators in rice supply chain. Rating scale from 1 to 5 that most closely matches the performance indicators for the rice supply chain in Cambodia:

5 = "strongly agree" refers to the reality that strongly suitable to the performance indicators

4 = "agree" refers to the reality that very suitable to the performance indicators

3 = "neutral" refers to the reality that moderately suitable to the performance indicators

2 = "disagree" refers to the reality that less suitable to the performance indicators

1 = "strongly disagree" refers to the reality that very less suitable to the performance indicators

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Table 29 Synthesizing latent and observed variables for performance

Latent variables	**Observed variables**
1. Environmental performance	1.1 The consumption rate of energy, which includes electricity and oil, is an important indicator 1.2 The consumption rate of natural resources such as water and land is an important indicator 1.3 The environmental pollutants (water, land, and air) is an important indicator
2. Social performance	2.1 Food insecurity (the scale of accessibility to foods and eating patterns) is an important indicator 2.2 Poverty is an important indicator 2.3 Farmers' knowledge is an important indicator
3. Economic performance	3.1 Rice yield of farming household is an important indicator 3.2 Rice quality (nutritional benefits, softness, aroma, and physical appearance) is an important indicator 3.3 Return on investment-ROI (net profit divided by the costs of investment) is an important indicator

Section 3 Risk management strategies. Rating scale from 1 to 5 that most closely matches the risk management strategies for the rice supply chain in Cambodia:

5 = "strongly agree" refers to the reality that strongly suitable to the risk management strategies

4 = "agree" refers to the reality that very suitable to the risk management strategies

3 = "neutral" refers to the reality that moderately suitable to the risk management strategies

2 = "disagree" refers to the reality that less suitable to the risk management strategies

1 = "strongly disagree" refers to the reality that very less suitable to the risk management strategies

Table 30 Risk management strategies in the rice supply chain management

Risk management strategies
1. Risk management strategies for supply risks
1.1 Seek alternative suppliers
1.2 Promote contract farming
1.3 Provide the incentive to local seed producers and distributors
1.4 Use the system of "sharing-hand": help each other during the farming period; improve agricultural management practices (e.g., using direct seeding)
1.5 Offer tax incentives to incentivize the imports of equipment and machinery
2. Risk management strategies for production risks
2.1 Improve agricultural management practices for biological risks (e.g., better water management, improve seeds); improve the agricultural extension services to commune level
2.2 Encourage agricultural microfinance
2.3 Encourage and promote policy on sustainable utilization of farming land (e.g., effective mapping)
2.4 Develop public policies and enforce for sanitary and phytosanitary standards (e.g., food safety); effective usage of pesticide and fertilizer; avoid risky practices through organic farms
2.5 Improve productivity by using high-yielding seed and modern agricultural techniques
2.6 Support and establish Farmer Organization
2.7 Improve agricultural training

Table 30 (Continued)

Risk management strategies
3. Risk management strategies for demand risks
3.1 Comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers
3.2 Improve transparency and market information
3.3 Promote contract farming with millers/ buyers
3.4 Improve warehouse management
3.5 Seek alternative buyers
4. Risk management strategies for environmental risks
4.1 Adapt for climate change (e.g., agricultural diversification); purchase insurance; aid or charity from government, international organization, and other donors
4.2 Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)
4.3 Construct and maintain roads in the countryside (link rice production areas \ to markets)
4.4 Reduce electricity price and promote electric power transmission to rural areas
4.5 Improve the agricultural extension services to commune level
4.6 Improve agricultural know-how training
4.7 Manage Covid-19 affects farmers by investing in the vaccination program, quarantine program, spraying program, strong health systems, advanced R & D

Part 3: Other recommendations and suggestions.

Validity and reliability

1. Validity

The researchers use the index of consistency (IOC) to examine the construct validity and the consistency (Pruekpramool, 2018). For instance, one author applied IOC to develop the system from entrepreneur to fair-trade for a food industry group by doing a study from 20 experts. The results demonstrated that IOC in all items is significant. All experts accepted all the topics, purpose, evaluation methodology, and other contents in the research (Suradom et al., 2013). Pruekpramool (2018) used IOC in the research (supply chain management of agricultural products in Thailand). The author brought the questionnaires to relevant experts to examine the conformity and content validity, including research questions, purpose and objectives of research, definition, terminology, and other appropriateness of the questionnaire by setting the criteria.

$$IOC = \frac{\sum_{i=1}^{N} R}{N}$$

Where $\sum$ R = the total of specialist score

N = the amount of specialist

IOC index contains three scores such as +1 (positive one), 0 (zero), -1 (negative one): score = +1 indicates that “suitable”; score=0 indicates that “not sure”; score = -1 indicates that “unsuitable”.

If IOC score ≤ 0.49 is excluded from the questionnaire, or else (“or else” means validity, readability, clarity, and comprehensiveness) (Muangpan, 2015).

Appendix B shows the list of experts. In this study, we requested five experts who earned Ph.D. degrees and have experience of more than five years to determine the IOC score. The overall IOC score is 0.9, as demonstrated in Appendix E-Results of Data Analysis.

2. Reliability

Cronbach’s alpha reliability (∝) is most commonly used for reliable measurement in social science and organizational science. It is controlled by testing the items in questionnaires for internal consistency reliability (Bonett & Wright, 2015; Trizano-Hermosilla & Alvarado, 2016). For example, Blair (2019) studied on relationship between the collaboration of the supply chain and the performance of punctual delivery and used Cronbach’s Alpha to know the reliability (the author’s research demonstrated that α = .69, which means moderate reliability). Another researcher introduced and pre-tested by selecting a target sample. The pilot was also used to evaluate the questions in the questionnaire by alpha value from

0 (i.e., low reliability) to 1 (high reliability). As a result of the author's study, the value of Cronbach's alpha is 0.89, which illustrates that good reliability (Muangpan, 2015). In general, reaching the value of alpha 0.70 or greater is an accepted thing and self-consistency (Taber, 2018).

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right)$$

Where:

α = Cronbach's alpha

k = the total of items or the total questions or the total components in a scale

$\sum_{i=1}^{k}\sigma_i^2$ = the sum of items variances (ith item)

σ_t^2 = the variance of the total scores or the variance of the scale scores (Arifin, 2018)

$\alpha \geq 0.9$ = Excellent

$0.9 > \alpha \geq 0.8$ = Good

$0.8 > \alpha \geq 0.7$ = Acceptable

$0.7 > \alpha \geq 0.6$ = Uncertain

$0.6 > \alpha \geq 0.5$ = Poor

$\alpha > 0.5$ = Rejected (Muangpan, 2015)

We tried out 30 samples (the second pilot test) to test variables using Chronbach's Alpha. In the second pilot test from 30 samples, the overall $\propto$ was 0.93, as illustrated in Appendix E-Results of Data Analysis for more details.

Data collection procedure

1. Primary data

First, the author requested an ethical letter for collecting data from the Human Ethics Research Committee (Burapha University). After getting approval (see Appendix D. Ethical Principles of Human Research), the author collects primary data. The primary data are collected from a fraction of the population- the sample- through data collection by conducting the interviews and making the observation. The semi-structured interviews are used by combining both unstructured interviewing and structured interviewing. Furthermore, it involves asking questions to get qualitative and quantitative data from the rice supply chain stakeholders.

2. Secondary data

The study used books, thesis/ dissertation, research journals, annual reviews, newsletters, and conference proceedings obtained from the Internet and library to get secondary data and official documents. Creswell and Creswell (2018) demonstrated that the document should be cited in the past ten years for reviewing the literature involving the research problems from introduction to a research proposal, but citing older documents is acceptable if they are essential and others have widely cited them. The author mainly cites the secondary data of this study in the ten years between 2013 and 2022 from Google Scholar, Science Direct, Academic Search Complete, ProQuest, Emerald, SpringerLink, and other reliable sources. Still, the author cites older documents if the documents are necessary, and others have widely cited them. Additionally, secondary information from government agencies (Ministry of Economy and Finance; Ministry of Agriculture, Forestry and Fisheries; Ministry of Planning; and other ministries involved with agriculture and trades) is great for this scientific study. Furthermore, international agencies, universities or institutions, and NGOs have provided valuable data for desk-level analysis.

Data analysis

The researcher uses IBM SPSS Amos, SPSS, and MS Excel to analyze the data. IBM SPSS Amos is a convenient application program for SEM (known as causal modeling or analysis of covariance structures). With Analysis of Moment Structures, Amos, it is easy to specify, assess the model's fit, modify, view, and print out the final result because of easy-to-use tools or graphical interface. Additionally, VB.NET Language or C# Language is another option for writing code in Amos to fit and specify the models if the researchers do not want to use tools or a graphical interface (Arbuckle, 2019). Furthermore, SPSS stands for Statistical Package for the Social Science, and the researcher uses it to analyze complex statistical data. The researcher uses Microsoft Excel to get the scientific outputs of complementation analysis.

1. Qualitative data analysis

Making and analyzing data are not sequential steps, which it is simultaneous (Figure 40). Working with qualitative data analysis includes recording annotations and memos; reviewing by reading to understand; coding to save data-which allows to classify or discover dimensions in data; making sense of data by reporting (Richards, 2014).

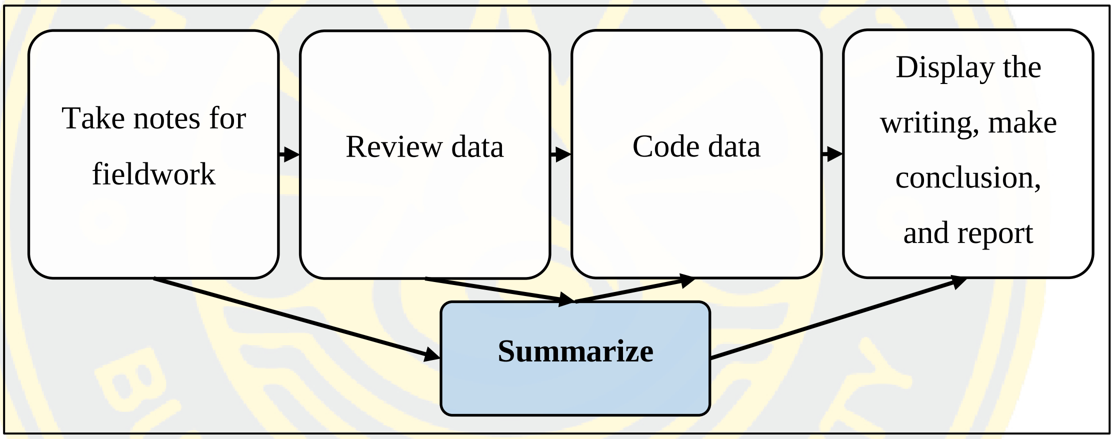

Figure 40 Qualitative data analysis

Sources: (Miles, M. B., & Huberman, A. M., 1994, as cited in Miles et al., 2014)

The researcher uses content analysis to analyze qualitative data in this scientific research. Three feathers typify content analysis: data reduction, a systematic way, and flexibility (Flick, 2013). Content analysis is a hybrid technique using statistical analysis and text analysis. For instance, it aims to decompose the texts to the categorized data by statistical frequency. Consistency, validity, reliability, and transparency make content analysis for good practice (Costa et al., 2019). Moreover, instrument development is built by using qualitative data, which converts data into classification and becomes factors (qualitative→quantitative) (Flick, 2017).

The researcher used narrative analysis to analyze qualitative data in this scientific study. The narrative analysis examined in detail about risks in the rice supply chain.

2. Quantitative data analysis

2.1 Descriptive and inferential statistics

Descriptive statistics deals with the illustration of numerical measures, while inferential statistics is related to using the techniques of statistics to make inferences about the entire population through samples (Kaushik & Mathur, 2014). The mean is the arithmetic average.

2.1.1 Mean

The mean is the arithmetic average.

$$\textit{Sample mean} = \bar{x} = \frac{x_1+x_2+x_3+\cdots+x_n}{n} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Where: n = the number of observations (x) in the sample

$$\textit{Population mean} = u = \frac{x_1+x_2+x_3+\cdots+x_N}{N} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Where: N = the number of items in the population-items of interest (Leech et al., 2014; Quirk & Palmer-Schuyler, 2016; Salkind, 2017).

2.1.2 Standard error

The standard deviation of the means is defined as the standard error.

$$s.e. = \frac{s}{\sqrt{n}}$$

Where: n = the sample size (Leech et al., 2014; Quirk & Palmer-Schuyler, 2016; Salkind, 2017).

2.1.3 Standard deviation

The standard deviation demonstrates how values are close to the average.

$$\textit{Sample standard deviation} = s = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$$

Where:

x = standard deviation of sample

$\bar{x}$ = the sample mean

n = the sample size

$\sum(x-\bar{x})^2$ = the sum of square deviations from average

Population standard deviation = $\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}}$

Where:

σ^2 = the variance of population

x = the value in each observation

μ = the mean of population

N = the population size

$\sum(x-\mu)^2$ = the sum of square deviations from population average (Leech et al., 2014; Quirk & Palmer-Schuyler, 2016; Salkind, 2017).

2.1.4. Skewness and Kurtosis

Skewness is an evaluation of the asymmetry and kurtosis is an evaluation of peakedness involved with a distribution (Cain et al., 2017; Kim, 2013; SENOCAK & VEHID, 2018). However, BPI Consulting (2016) and Westfall (2014) said that kurtosis is the evaluation for the sizes of the two tails-noting about the shape of the peakedness.

Skewness and kurtosis of the distribution are used for normality assessment (Kim, 2013). According to Zheng et al. (2016) reviewed about zero skewed (mode=median=mean) with a perfectly symmetrical data set, positively skewed (mode < median < mean), negatively skewed (mean < median < mode). BPI Consulting (2016) illustrated that if the value of kurtosis is more than 3, and then it is more in the tails than the normal distribution; if the value of kurtosis is less than 3, and then it is less in the tails than the normal distribution-it means that more decreases in kurtosis is lighter in tails (namely a platykurtic distribution) and more increases in kurtosis is more heavier in tails (namely a leptokurtic distribution). The data is still considered to be normal if the kurtosis value is between -10 and +10 and the skew value between -2 and +2 (Collier, 2020).

2.2 Structure equation modeling (SEM)

SEM and statistical tools are employed for this study. SEM enables 5 **Cs** such as 1) **constructs** or latent variables (measuring by observed variable and assessing measurement quality, 2) **complexity** (dealing with the actual complication of phenomena related to bivariate and univariate statistics), 3) **conjointly** (estimating of relationships between variables, analyzing factor and path, measuring and predicting), 4) **confirmatory** (specifying the model as stated by theory), and 5) **co-variances** (measuring for observed co-variances) (Batista & Coenders, 2000, as cited in Coromina, 2014). The sophisticated statistical tools are employed to get the meaningful result of the research findings.

The researcher employs the structural equation model (SEM) for investigating risks that affect rice supply chain performance (environmental, social, and economic aspects). The measurement equations are given by

$$y = \tau_y + \Lambda_y + \eta + \varepsilon \ (1)$$

$$x = \tau_x + \Lambda_x + \xi + \delta \ (2)$$

where y and x are vectors of observed variables of latent vectors η and ξ; Λ_y and Λ_y are regression coefficient matrices in the equations; ε and δ are errors in the measurement equations; τ_y and τ_x are vectors of intercept terms.

SEM is represented as

$$\eta = \alpha + B\eta + \Gamma\xi + \zeta \ (3)$$

where $\eta = (\eta_1, \eta_2, \dots, \eta_m)$ and $\xi = (\xi_1, \xi_2, \dots, \xi_n)$ are random vectors of endogenous latent variables and exogenous latent variables, respectively.

Vectors η and ξ cannot be observed directly; however, vectors $y = (y_1, y_2, \dots, y_p)$ and $x = (x_1, x_2, \dots, x_q)$ are observed. Alpha (α) is a vector of intercept terms; B and Γ are regression coefficient matrices; $\zeta = (\zeta_1, \zeta_2, \dots, \zeta_m)$ is a random vector of latent error variables (See Jöreskog et al., 2016).

Criteria for determining fit indices include as following:

1. Chi-square (X^2) and Chi-square to degree of freedom: it is a non-parametric tools for analyzing goodness-of-fit (test for equal expected frequencies, test for unequal expected frequencies-the significance of population, and test for normality-comparing observed frequencies to the theoretical normal distribution),

contingency table (cross-tabulation) (Wheaton, 1977, as cited in MacInnes, 2016; McHugh, 2013; Onchiri, 2013; Phagwara, 2014; Salkind, 2017; Singhal & Rana, 2015). Wan Omar and Hussin (2013) used chi-square to degree of freedom to measure the model-fit. The document demonstrated that the accepted level is p-value > 0.05 (absolute fit) and Chi- Square/ df < 3.0 (parsimonious fit) as demonstrated by Wheaton (1977) as cited in Awang (2015) and Marsh and Hocevar, 1985, as cited in Awang (2015). However, Schumacker and Lomax (2016) illustrated that X^2/ df < 2 and p-value > 0.05 are a satisfactory fit.

2. Root mean square error of approximation (RMSEA): it is used widely to evaluate the fit of the structural equation model (Lai & Green, 2016; Savalei, 2018). The value of RMSEA ≤ 0.05 indicates that the model fits well, according to empirical experience (Browne and Cudeck, 1993, as cited in Loehlin & Beaujean, 2016). Taasoobshirazi and Wang (2016) suggested that scientific researchers should keep away from presenting RMSEA when sample sizes are lower than 200, especially when degrees of freedom are small.

3. Root mean square residual (RMR): A value smaller than 0.08 is generally recognized as a good fit (Hu and Bentler, 1999, as cited in Rha, 2013) and the value of RMR equals zero means a perfect fit (Ritter, 2014). However, Schumacker and Lomax (2016) illustrated that RMR<.05 is a satisfactory fit.

4. Goodness-of-fit index (GFI): The sample size affects the goodness-of-fit index (GFI), which is used for assessing the model fit. The levels of acceptable threshold is > 0.90 as illustrated by Hooper (2008) as cited in Ainur et al. (2017) and Joreskog and Sorbom (1984) as cited in Awang (2015). But, Schumacker and Lomax (2016) demonstrated that GFI > 0.95 is a satisfactory fit.

5. Normed Fit Index (NFI): it is the measure of relative fitness. The index ranges from 0 to 1, which 0.9 means a good fit (Ranaiefar, 2013) or >0.9 is accepted (Arunothong, 2014; Jeong, 2018). If the sample size less than 200, it underestimates the goodness of fit (Ranaiefar, 2013). But, Schumacker and Lomax (2016) demonstrated that NFI > 0.95 is a satisfactory fit.

6. Tucker-Lewis index (TLI): Via the structural equation model by using Amos, the researcher included TLI in model fit summary to analyze the goodness of fit (Smith, 2018). TLI is 0-1 range which is used for evaluating the fit improvement

(Bentler, 1990, as cited in Lee, 2013) and recommended value for the acceptable threshold is > 0.90 (Jeong, 2018; Lee, 2013) and recommended value for desirable one is > 0.95 (Hu & Bentler, 1999, as cited in Lee, 2013).

The researcher decided to follow Schumacker and Lomax (2016) for a satisfactory fit (Table 31). Once the parameters are estimated, this model is tested by employing the minimum fit function value as follows:

Table 31 A summary of model fit indices for SEM in this study

No	Model fit	Criteria
1	X^2	-Chi- Square/ df < 2.0 -p-value > .05
2	RMSEA	<.05
3	RMR	<.05
4	GFI	>.95
5	NFI	>.95
6	TLI	>.95

(Schumacker & Lomax, 2016)

Conclusion

This chapter aimed to explain the research methodology. It involved as follows: 1) site selection, 2) research design and process, 3) sample size and sampling methods, 4) reviewing and applying the paradigm, 5) synthesizing the variables and questionnaire design, 6) validity and reliability, 7) data collection procedure, 8) data analysis, 9) conclusion. The following chapter offers the research results, which involved three research questions: 1) What are the agricultural risk factors affecting the RSC?, 2) What are the effects of risk factors on RSC performance?, and 3) What actions should stakeholders take to manage the RSC risks?

CHAPTER 4
RESEARCH RESULTS

This chapter aims to represent the results of data analysis as follows:

1. To identify the agricultural risk factors in the rice supply chain (RSC) in Cambodia

2. To investigate risk factors that affect to rice supply chain performance in Cambodia

3. To propose risk management strategies in the sustainable rice supply chain management in Cambodia

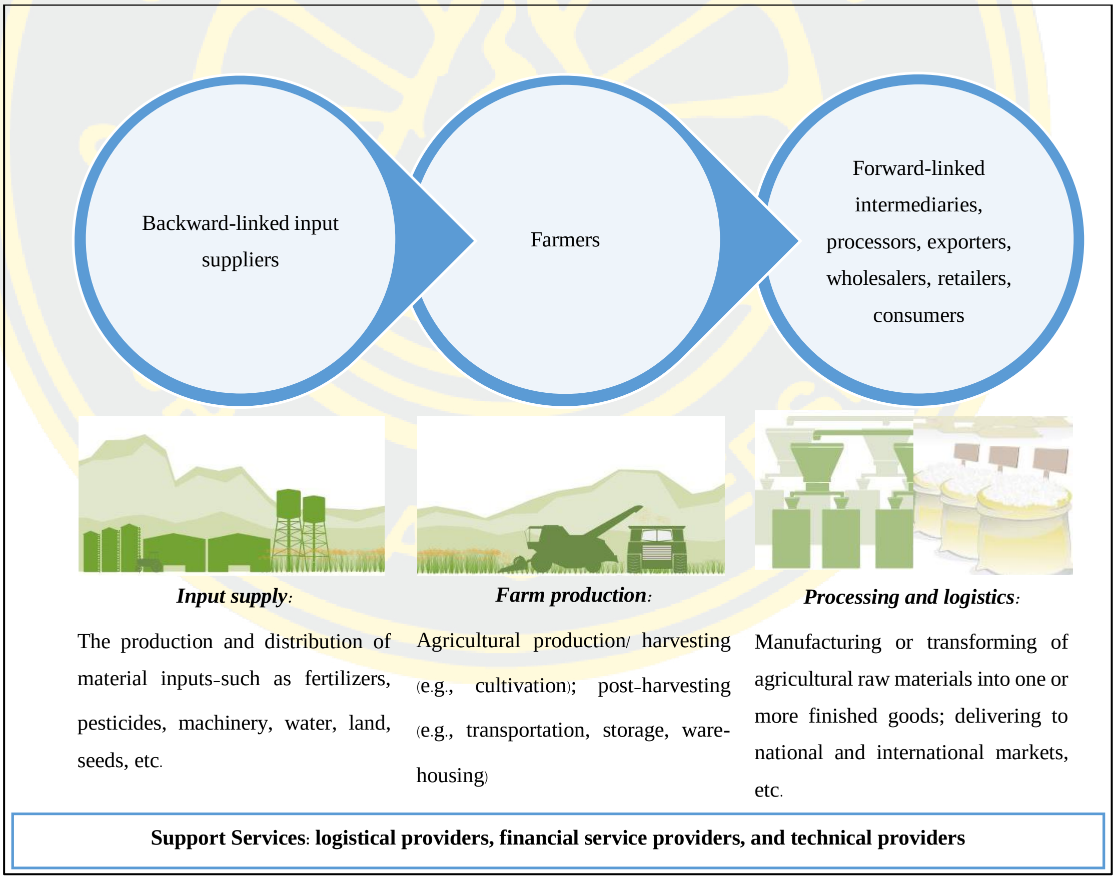

Figure 41 The concept of the rice supply chain in Cambodia

Abbreviations and symbols in this data analysis depict more details in Appendix E.

Risk identification of rice supply chain

1. Risk identification from literature review

Analysis of the frequency of mention from literature review (Table 32 and 33) indicated that the farmers encountered eighteen risk factors. The researchers consolidated eighteen risk factors into four categories: supply risks, production risks, demand risks, and environmental risks. Moreover, analysis of the existing studies illustrated that production risks occurred most often in the literature, mentioned in 20 of 28 articles, followed by environmental risks (19/ 28), supply risks (14/ 28), and demand risks (8/ 28). The frequency of mention did not significantly reflect the prioritization of risk. The prioritization of risk factors in the supply chain depended on the highest risk to the lowest risk concerning the likelihood of occurrence, the effect, etc. Thus, the frequency analysis showed that some risk factors are illustrated commonly in the agricultural supply chain.

Table 32 Classification of significant risks

Risk factors in rice supply chain	Obs. Var.	Count
The factors of Supply Risks (SR)		
1. Rising costs of raw materials (fertilizer, pesticide, high yield seeds, and fuel)	SR1	3
2. Rising costs of services (transportation, labor, interest rates or/ and credit, and other agricultural services)	SR2	6
3. Lack of high yield seeds	SR3	3
4. Lack of labor	SR4	10
5. Lack of equipment and machinery	SR5	2

Table 32 (Continued)

Risk factors in rice supply chain	Obs. Var.	Count
The factors of Production Risks (PR)		
6. Biological risks such as weeds, pests, and crop diseases	PR6	16
7. Lack of financial capital	PR7	4
8. Misuse of fertilizer or/ and pesticide	PR8	7
9. Lack of agricultural know-how	PR9	11
The factors of Demand Risks (DR)		
10. Low prices of rice products	DR10	4
11. Lack of market information	DR11	2
12. Uncertainty of market demand for quantity	DR12	1
13. Uncertainty of market demand for quality or/ and food safety requirements	DR13	1
The factors of Environmental Risks (ER)		
14. Natural disasters (flood, drought)	ER14	15
15. Lack of irrigation systems	ER15	10
16. Lack or poor condition of basic infrastructure (roads, electricity)	ER16	3
17. Inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services)	ER17	5
18. Pandemic risks (Covid-19)	ER18	1

Table 33 Articles by factors in Cambodia

No	Author (s)	Risk Factors (observed variables)
1	Bairagi et al. (2020)	PR6, ER14
2	Castilla et al. (2019)	PR6, PR9
3	Ches and Yamaji (2016)	SR2, SR4
4	Chhun et al. (2019)	PR6, PR9
5	Dalgliesh et al. (2016)	SR1, SR2, ER14

Table 33 (Continued)

No	Author (s)	Risk Factors (observed variables)
6	Dany et al. (2015)	ER14, ER17
7	Flor et al. (2018)	SR4, PR6, PR8, ER14, ER17
8	Flor, Maat, Hadi, Kumar, et al. (2019)	PR6, PR8
9	Flor, Maat, Hadi, Then, et al. (2019)	PR6, PR8, PR9
10	Grunfeld and Ng (2013)	PR9
11	Horita (2016)	DR10, DR12, DR13
12	Hossain (2018)	ER18
13	Iwahashi et al. (2021)	SR4, PR6, ER14, ER15
14	Kea et al. (2016)	SR2, SR5, PR6, PR7, PR8, PR9, ER14, ER15, ER16, ER17
15	Kong and Castella (2021)	DR10, ER14
16	Mao et al. (2014)	SR1, SR4, SR5, PR6, PR7, PR8, PR9, DR10, DR11, ER14, ER15, ER16, ER17
17	Martin (2017)	SR4, PR6, PR9, ER14
18	Martin et al. (2021)	SR2, SR4, PR6, PR8, PR9, ER14, ER15
19	Mishra et al. (2018)	SR1, SR2, SR3, PR7, PR9, DR11, ER14, ER15
20	Montgomery et al. (2017)	SR3, SR4, PR6, PR7, DR10, ER14, ER15
21	Nguyen et al. (2019)	SR4, PR6, ER14, ER15, ER16
22	Schreinemachers et al. (2015)	PR8, PR9, ER17
23	Schuch et al. (2021)	ER15
24	Seng (2014)	SR4, PR6, ER14, ER15
25	Sithirith (2017)	ER15
26	Turner et al. (2017)	SR3, PR9
27	Wokker et al. (2014)	PR6, ER14
28	Xangsayasane et al. (2019)	SR2, SR4, PR6

2. Results from the first pilot test for risk identification

Table 34 illustrates the informants' profiles, which are sex, marital status, age, educational level, and rice farming experience from the first try-out (n = 20 samples).

Table 34 Number and percentage of informants from the first pilot

Variable	Type	Number	Percentage
Sex	Male	16	80
	Female	4	20
Marital status	Single	5	25
	Married	15	75
Age	Under 30	6	30
	30-39 years old	10	50
	Older than 40 years	4	20
Educational level	Primary school	2	10
	Junior high school	2	10
	Senior high school	2	10
	Bachelor	10	50
	Master	4	20
Rice farming experience	Less than 5 years	5	25
	5-10 years	7	35
	11-15 years	4	20
	16-20 years	2	10
	More than 20 years	2	10

In the first pilot test, out of 20 respondents, only 20 percent are female; 80 percent are male. Out of 20 informants, only 25 percent are single; 75 percent are married. The smallest group of respondents aged over 40 years old accounts for 20 percent; the group of respondents aged under 30 years old accounts for 30 percent, while the biggest group of respondents aged 30-39 years old accounts for 50 percent. On the other hand, the level of education that informants have completed is Primary-school level (10 percent), Junior high school (10 percent), Senior high school (10 percent), Master's degree (20 percent), and Bachelor's Degree (50 percent). The respondents have experienced between 16 and 20 years (n = 2; 10 percent), more than 20 years (n = 2; 10 percent), 11-15 years (n = 4; 20 percent), and less than 5 years (n = 5; 25 percent) in the current position. However, the largest group of informants (n = 7; 35 percent) has experienced rice farming within 5-10 years.

The primary purpose of the first pilot test (n = 20) is to confirm factors and add more farmers' risk factors. After confirming and adding them, the results indicate that the farmers face eighteen risk factors, as demonstrated in Table 35.

Table 35 Confirming and adding more risk factors from the first pilot

RISK	Number	Percentage
The factors of supply risks (SR)		
1. Rising costs of raw materials (fertilizer, pesticide, | high yield seeds, fuel)	11	55
2. Rising costs of services (transportation, labor, interest rates or/ and credit, other agricultural services)	7	35
3. Lack of high yield seeds	6	30
4. Lack of labor	2	10
5. Lack of equipment and machinery	8	40
The factors of production risks (PR)		
6. Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)	7	35
7. Lack of financial capital	4	20
8. Misuse of fertilizer or/ and pesticide	10	50
9. Lack of agricultural know-how	9	45

Table 35 (Continued)

RISK	Number	Percentage
The factors of demand risks (DR)		
10. Low prices of rice products	20	100
11. Lack of market information	1	5
12. Uncertainty of market demand for quantity	10	50
13. Uncertainty of market demand for quality or/ and food safety requirements	10	50
The factors of environmental risks (ER)		
14. Natural disasters (flood, drought)	16	80
15. Lack of irrigation systems	18	90
16. Lack or poor condition of basic infrastructure (roads, electricity)	1	5
17. Inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services)	20	100
18. Pandemic risks (Covid-19)	2	10

3. Personal details of experts

The table 36 shows the experts' profiles (n = 10 samples), which are sex, marital status, age, educational level, and rice farming experience. Out of 10 experts, only 20 percent are female; 80 percent are male. Out of 10 informants, only 20 percent are married; 80 percent are single. The smallest group of respondents aged 40-49 years old accounts for 10 percent. The respondents aged 30-39 years old are 30 percent, while the biggest group of respondents aged under 30 years old accounts for 60 percent. On the other hand, the level of education that the smallest group of experts have completed is Ph.D. level (10 percent), whereas Master’s Degree (90 percent). The smallest group of respondents have rice farming experiences within 16-20 years (n = 1; 10 percent) and 11-15 years (n = 3; 30 percent) in the current position. However, the largest group of informants (n = 6; 60 percent) have experienced it within 5-10 years.

Table 36 Frequency and percent of informants (experts)

		Total (n1 = 10 experts)	
		Frequency	**Percent**
Sex	Male	8	80.0
	Female	2	20.0
Marital status	Single	8	80.0
	Married	2	20.0
Age	Under 30 years old	6	60.0
	30-39 years old	3	30.0
	40-49 years old	1	10.0
Educational level	Master	9	90.0
	Ph.D.	1	10.0
Rice farming experience	5-10 years	6	60.0
	11-15 years	3	30.0
	16-20 years	1	10.0

4. Risk prioritization in the Cambodian rice supply chain

The researcher conducted in-depth interviews with experts to prioritize risk factors. The arithmetic mean of all experts was found to be 4.30 on the five-point Likert scale ranging from “strongly disagree” to “strongly agree”. Nine experts (90 percent) consider themselves “highly vulnerable” (point 4 or 5 on the Likert scale), while only one expert deemed their position to be “neutral” (point 3 on the Likert scale).

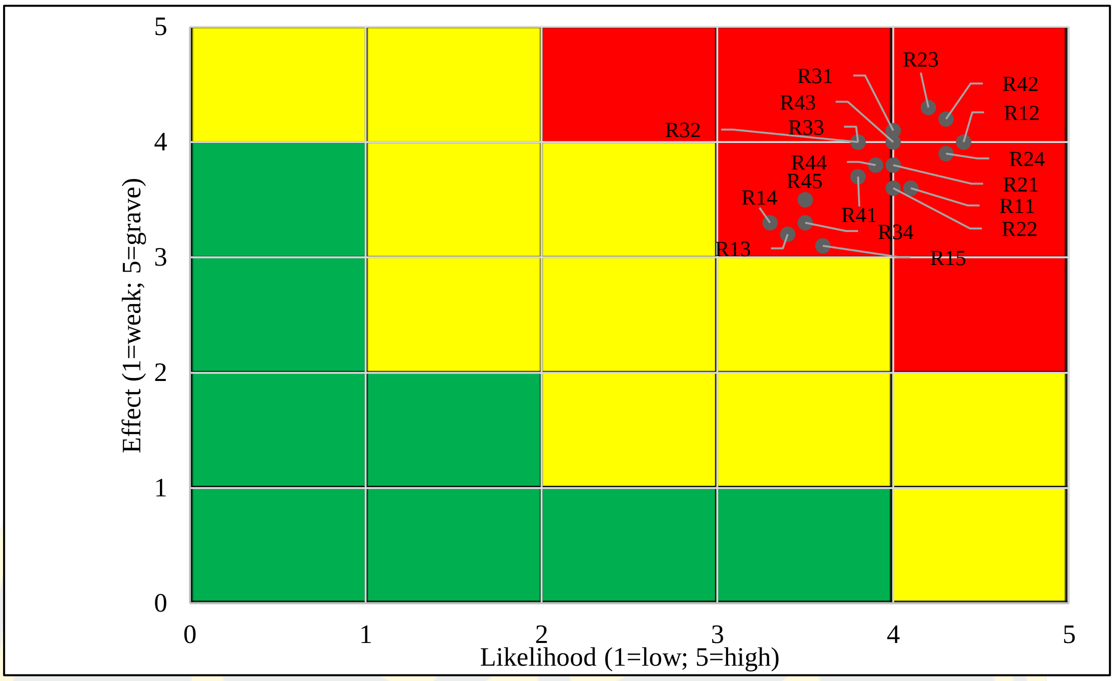

Figure 42 Risk assessment matrix of rice supply chain in Cambodia

The 18 risk factors are depicted in the "likelihood/ effect"-matrix. The risks in the rice supply chain in Cambodia can be compared concerning their likelihood of occurrence and their effect. The most critical risks in the rice supply chain can also be identified. Figure 42 demonstrates the "likelihood/ effect" -matrix result.

More importantly, the researcher asked the experts to estimate the risk prioritization in their rice supply chain. The risk prioritization relied on expected loss (expected loss scenarios = likelihood*effect). Figure 43 depicts these results.

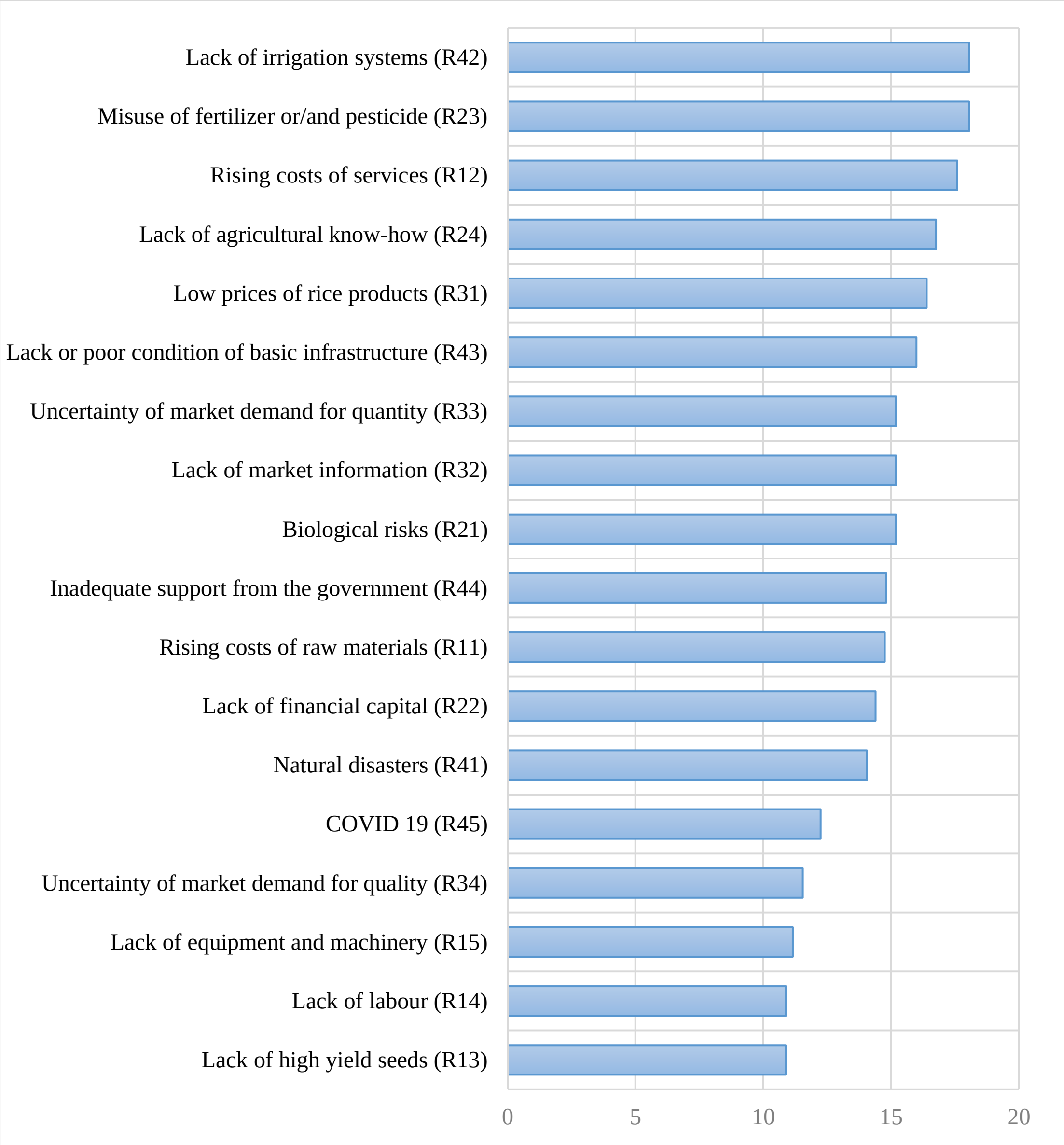

Figure 43 Risk prioritization in the rice supply chain

Risk investigation of rice supply chain

1. The results of study sample

The table 37 illustrates the Cambodian farmers' profiles (n = 200 samples), which are sex, marital status, age, educational level, and rice farming experience.

Table 37 Frequency and percent of participants (Cambodian farmers)

		Total (n2 = 200 farmers)	
		Frequency	**Percent**
Sex	Male	123	61.5
	Female	77	38.5
Marital status	Single	116	58.0
	Married	80	40.0
	Widow/ widower	4	2.0
Age	Under 30 years old	116	58.0
	30-39 years old	59	29.5
	40-49 years old	14	7.0
	Older than to 50 years	11	5.5
Educational level	Never go to school	2	1.0
	Preschool	2	1.0
	Primary school	11	5.5
	Junior high school	12	6.0
	Senior high School	97	48.5
	Bachelor	63	31.5
	Master	12	6.0
	Ph.D.	1	.5
Rice farming experience	Less than 5 years	115	57.5
	5-10 years	50	25.0
	11-15 years	15	7.5
	16-20 years	5	2.5
	More than 20 years	15	7.5

The findings indicate that most informants (61.5 percent) are male, while 38.5 percent are female by random sampling. Some 116 or 58.0 percent of respondents are single, 40.0 percent are married, and only 2.0 percent are widows/ widowers. Samples are under 30 years old, accounting for 58.0 percent of all age ranks; followed by the respondents aged 30-39 years old, accounting for 29.5 percent of respondents; the respondents aged 40-49 years old, accounting for 7 percent; the respondents aged more than 50 years, accounting for 5.5 percent respectively. Moreover, the research findings demonstrate that Senior high school (n = 97; 48.50 percent), Bachelor's degree (n = 63; 31.50 percent), Junior high school (n = 12; 6 percent), Master's degree (n = 12; 6 percent), Primary school (n = 11; 5.50 percent), Never going to school (n = 2; 1 percent), Preschool (n = 2; 1 percent), and Ph.D. degree (n = 1; 0.50 percent). We categorize rice farming experience into five classifications: less than five years, 5-10 years, 11-15 years, more than 20 years, and 16-20 years; the percentages are 57.50, 25, 7.50, 7.50, and 2.50, respectively.

Table 38 Descriptive statistics of all risk factors and performances (n = 200)

RISK		$\bar{x}$	SD	CV (percent)	SK	KU
The factors of supply risks (SR)						
1. Rising costs of raw materials (fertilizer, pesticide, high yield seeds, fuel)	R11	4.1	1.1	26.0	(1.4)	1.6
2. Rising costs of services (transportation, labor, interest rates or/ and credit, other agricultural services)	R12	3.9	1.0	24.7	(1.0)	0.8
3. Lack of high yield seeds	R13	3.8	0.9	24.8	(0.6)	0.2
4. Lack of labor	R14	3.6	1.0	28.7	(0.6)	0.0
5. Lack of equipment and machinery	R15	3.8	1.0	26.3	(0.6)	(0.1)

Table 38 (Continued)

RISK		$\overline{x}$	SD	CV (percent)	SK	KU
The factors of production risks (PR)						
6. Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)	R21	4.0	0.9	22.3	(0.9)	0.8
7. Lack of financial capital	R22	4.0	0.9	21.8	(0.7)	0.1
8. Misuse of fertilizer or/ and pesticide	R23	3.9	0.9	23.1	(1.1)	1.5
9. Lack of agricultural know-how	R24	4.1	0.8	19.0	(0.8)	1.0
The factors of demand risks (DR)						
10. Low prices of rice products	R31	4.4	1.0	22.6	(1.9)	3.4
11. Lack of market information	R32	4.3	0.9	20.4	(1.5)	2.7
12. Uncertainty of market demand for quantity	R33	4.1	0.9	22.1	(1.2)	1.7
13. Uncertainty of market demand for quality or/ and food safety requirements	R34	4.1	0.8	20.2	(0.8)	0.5
The factors of environmental risks (ER)						
14. Natural disasters (flood, drought)	R41	4.1	0.9	21.3	(0.7)	0.1
15. Lack of irrigation systems	R42	4.2	0.8	19.7	(1.1)	1.5
16. Lack or poor condition of basic infrastructure (roads, electricity)	R43	3.9	0.9	23.3	(0.6)	0.2

Table 38 (Continued)

RISK		$\bar{x}$	SD	CV (percent)	SK	KU
17. Inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services)	R44	4.0	0.9	21.9	(0.8)	0.3
18. Pandemic risks (Covid-19)	R45	4.1	1.0	23.5	(1.1)	0.9
Environmental performance (ENVI)						
1. The consumption rate of energy, which includes electricity and oil	P11	3.9	0.8	22.1	(0.8)	1.2
2. The consumption rate of natural resources such as water and land	P12	3.8	0.7	19.7	(0.8)	1.9
3. The environmental pollutants (water, land, and air)	P13	4.0	0.9	23.4	(0.9)	0.9
Social performance (SOC)						
4. Food insecurity (the scale of accessibility to foods and eating patterns)	P21	3.7	0.8	22.8	(0.5)	0.3
5. Poverty	P22	4.1	0.9	22.4	(0.9)	0.8
6. Farmers’ knowledge	P23	4.0	0.8	20.7	(0.7)	0.8
Economic performance (ECON)						
7. Rice yield of farming household	P31	3.9	0.9	21.8	(0.6)	0.4
8. Rice quality (nutritional benefits, softness, aroma, and physical appearance)	P32	3.8	0.8	21.4	(0.6)	0.7
9. Return on investment-ROI (net profit divided by the costs of investment)	P33	4.0	0.9	22.0	(0.7)	0.5

Table 38 shows descriptive statistics of all risk factors and performances (sample = 200 farmers).

The supply risks (latent variables) are measured by five risk factors. The highest mean score is (R11) rising costs of raw materials (fertilizer, pesticide, high yield seeds, fuel); followed by (R12) rising costs of services (transportation, labor, interest rates or/ and credit, other agricultural services); (R13) lack of high yield seeds; (R15) lack of equipment and machinery; (R14) lack of labor.

The production risks (latent variables) are measured by four risk factors. The highest mean score is (R24) lack of agricultural know-how; followed by (R21) biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi); (R22) lack of financial capital; (R23) misuse of fertilizer or/and pesticide.

The demand risks (latent variables) are measured by four risk factors. The highest mean score is (R31) low prices of rice products; followed by (R32) lack of market information; (R33) uncertainty of market demand for quantity; (R34) uncertainty of market demand for quality or/and food safety requirements.

The environmental risks (latent variables) are measured by five risk factors. The highest mean score is (R42) lack of irrigation systems; followed by (R41) natural disasters (flood, drought); (R45) pandemic risks (Covid-19); (R44) inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services); (R43) lack or poor condition of basic infrastructure (roads, electricity).

The environmental performances (latent variables) are measured by three indicators. The highest mean score is (P13) the environmental pollutants (water, land, and air); followed by (P11) the consumption rate of energy, which includes electricity and oil; (P12) the consumption rate of natural resources such as water and land.

The social performances (latent variables) are measured by three indicators. The highest mean score is (P22) poverty; followed by (P23) farmers' knowledge; (P21) food insecurity (the scale of accessibility to foods and eating patterns).

The economic performances (latent variables) are measured by three indicators. The highest mean score is (P33) return on investment-ROI (net profit divided by the costs of investment); followed by (P31) rice yield of farming household; (P32) rice quality (nutritional benefits, softness, aroma, and physical appearance).

Participant 1

"…We lack irrigation systems and water…", "…The low rice market prices and expensive agricultural inputs prevent us from operating profitably. We have problems with inorganic fertilizer and pesticide prices…"

Participant 2

"…We don't have farming skills and knowledge, and our farming relies on rainfall for water. We use traditional methods, which we learned from our ancestors…"

Participant 3

"…Issues: lack of high-yield seeds, lack of labor, lack of financial capital, and lack of equipment and machinery. Our income from selling rice products are insufficient for loan payments, and we will face risks in term of selling our assets to pay the loan. I use traditional agricultural inputs, oxen, and buffaloes for my farming…"

Participant 4

"…The villagers don't know how to use pesticides and other chemicals properly. The villagers overuse chemical fertilizers…"

Participant 5 and Participant 9

"…We confront floods in the rainy season and drought in the dry season. We do not have enough water in irrigation canals and rivers during July and August. Moreover, we can't farm many times because of poor water management practices (including inequalities in the water supply)…"

Participant 6 and participant 7

"…Problems are weeds, pests, crop diseases, lack of market information, and Covid-19…", "…There usually isn't sufficient water in irrigation systems…"

Participant 8

"…Low soil fertility for rice farming is our concern…"

Participant 9

"…The government's support is insufficient for basic infrastructure, agricultural know-how training, and public interventions. We need not only agricultural know-how training but also training on effective financial management…", "…During harvest seasons, buyers and traders want to buy high-quality rice; our low-quality rice is difficult to sell. Because of the poor condition of roads and inaccessibility of threshing suppliers in the rainy season, we face difficulty in the stages of post-harvest handling of rice grains. As a result, our rice grains become black (low quality). When rice products are low quality, there is no good market to sell them…", "…Rice farming is extremely vulnerable to many risks and requires sustained efforts over the long term…"

2. The structural equation model for risk investigation

As it can be seen from Figures 42 and 43 (risk assessment matrix and risk prioritization of rice supply chain), expected loss scenarios are high. Hence, the researcher attempted to gain some in-depth insights for investigating 18 risk factors that affect rice supply chain performance in Cambodia. The structural equation model, known as causal modeling or analysis of covariance structures, is used in the second objective for investigating.

The researchers employ SEM because it is a useful statistical tool to analyze the relationship between latent variables. Latent variables refer to latent factors that researchers cannot observe directly. Instead, they are estimated by a set of manifest variables. Manifest variables (observed variables) are measured directly by the researchers.

Given the circumstances of the stakeholders in the research area, as well as the supply chain condition in which they are, this scientific research attempts to investigate the four main research hypotheses:

H1: Rice supply chain performance is significantly affected by the rice supply chain risks (H_1).

H2: There is a relationship between environmental performance and social performance (H_1).

H3: There is a relationship between social performance and economic performance (H_1).

H4: There is a relationship between environmental performance and economic performance (H_1).

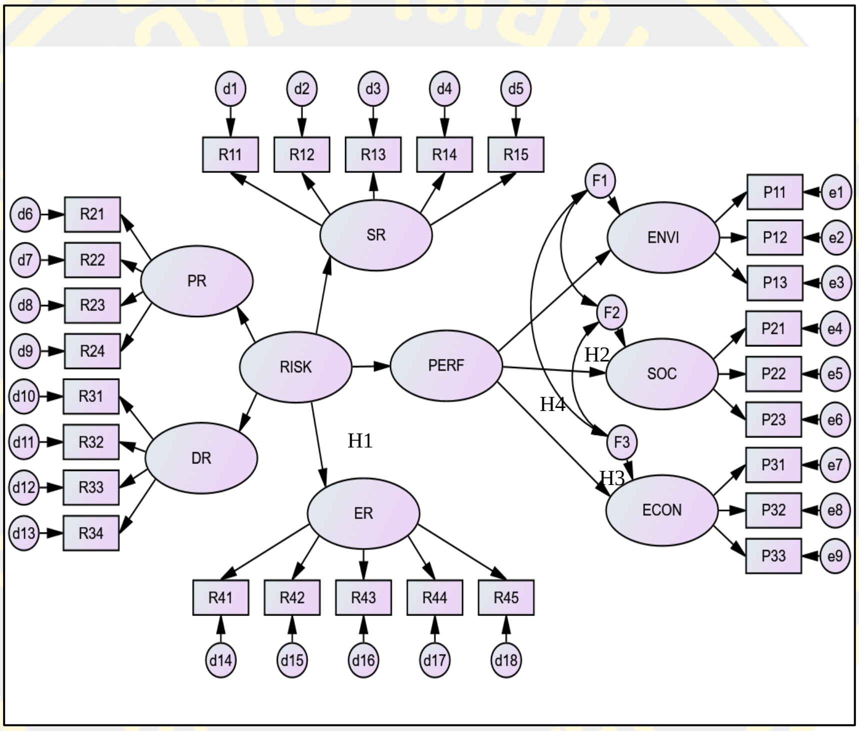

Figure 44 Research conceptual model: SEM

To analyze the structural equation model (SEM), the researcher had to first check the assumptions of SEM, such as normality, no systematic missing data, linear relationships, adequate sample size, correct model specification, etc. There is an assumption that the normality of the data can be ascertained by checking the mean, standard deviation, coefficient of variation, skewness, and kurtosis. The data is still considered to be normal if the kurtosis value is between -10 and +10 and the skew value between -2 and +2 (Collier, 2020). The research results demonstrate that the data is normal (Table 38).

Initially, the researcher analyzes the first measurement model (risks) and second measurement model (performances). If measurement models (Figure 45 and 46) are acceptable, we analyze the full research model (Figure 44). Both the first and second measurement models showed the need for modification (e.g., Figure 47).

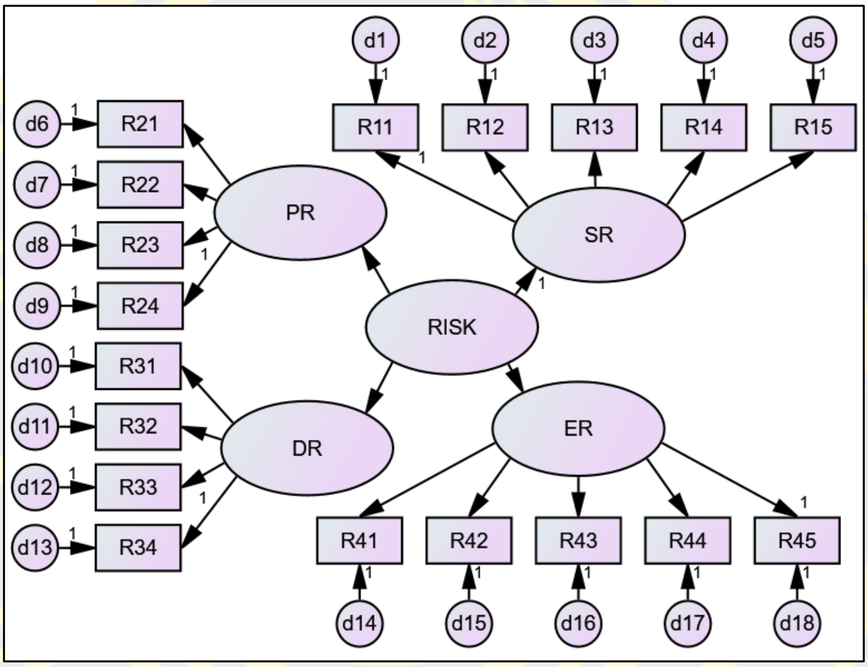

Figure 45 Measurement model 1: risks

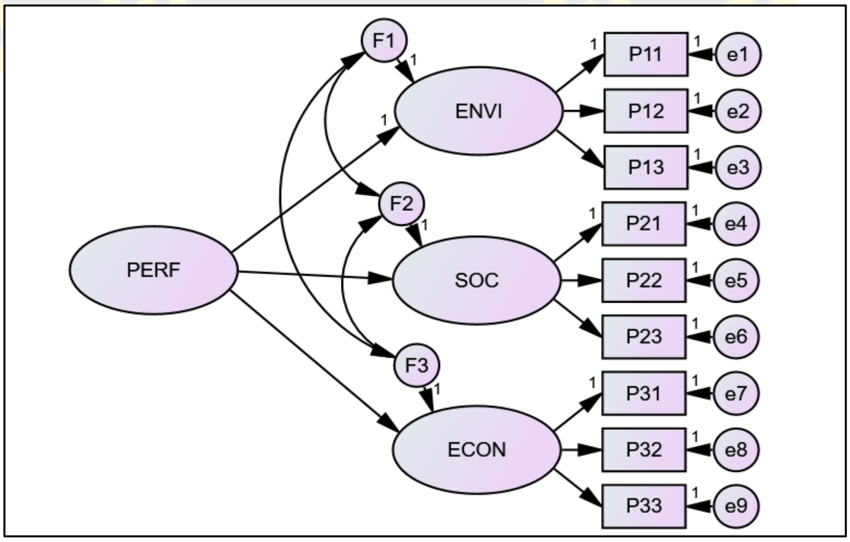

Figure 46 Measurement model 2: Performances

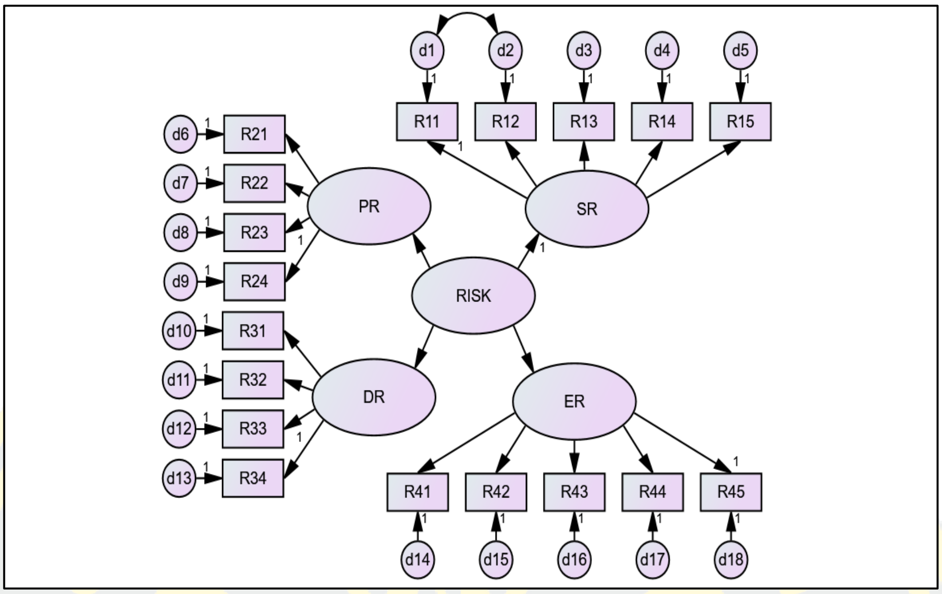

Figure 47 Modification measurement model 1 (risks)

Table 39 shows that chi-square (X^2) = 116.139; degrees of freedom (df) = 205; relative chi-square (X^2/ df) = 0.567; *p*-value = 1.000; root mean square error of approximation (RMSEA) = 0.000; root mean square residual (RMR) = 0.026; goodness-of-fit index (GFI) = 0.960; normed fit index (NFI) = 0.951; Tucker-Lewis index (TLI) = 1.076. Following Schumacker and Lomax (2016), model-fit criteria are X^2/ df < 2; *p*-value > .05; RMSEA, RMR<.05; GFI, NFI, TLI >.95. Therefore, the structural equation model of this study is deemed to be a satisfactory fit.

It is required that the critical ratio (C.R.) be greater than 1.96 in order for the estimates to be considered significant (Schumacker & Lomax, 2016). We found that all estimates are positive values following logical directions (Figure 48 and Table 39). The C.R. for the estimates in this study ranges from 2.681 to 6.020, as demonstrated in (Table 40). In this regard, we can make decisions and form to the conclusions as follows:

- H1: t=3.480*** > 1.96. The test is significantly different from zero at the 0.001 level (two-tailed). H_0 is rejected. Rice supply chain performance is significantly affected by the rice supply chain risks.

- H2: t=2.681** > 1.96. The test is significantly different from zero at the 0.01 level (two-tailed). H_0 is rejected. There is a relationship between environmental performance and social performance.

- H3: t=4.604*** > 1.96. The test is significantly different from zero at the 0.001 level (two-tailed). H_0 is rejected. There is a relationship between social performance and economic performance.

- H4: t=3.515*** > 1.96. H_0 is rejected. The test is significantly different from zero at the 0.001 level (two-tailed). There is a relationship between environmental performance and economic performance.

The squared multiple correlation coefficient (SMC or R^2) shows the proportion of the total variation accounted for or explained for in the dependent variables (Y) by the set of independent predictor variables (X) (Schumacker & Lomax, 2016). It is required that R^2 be greater than 0.30 for good variables (Bavarsad et al., 2014). Table 39 shows all SMCs in this study are greater than 0.30, and all standardized regression weights (Table 40) are considered to be significant. More importantly, environmental performance can demonstrate 81.2 percent of the variances of the RSC performance.

From the analysis of the risk on performances (observed variables), the environmental pollutant (P13) has the highest-effect value, followed by the consumption rate of natural resources (P12), the consumption rate of energy (P11), poverty (P22), rice yield (P31), farmers' knowledge (P23), food insecurity (P21), return on investment (P33), rice quality (P32). The standardized indirect (mediated) effect of risk on performances is 0.612, 0.578, 0.501, 0.467, 0.454, 0.454, 0.409, 0.349, and 0.327, respectively. Also, the analysis shows that the low price of rice products (R31) is the most critical factor. When demand risk goes up by 1 standard deviation, R31 goes up by 0.67 standard deviation (Figure 48).

According to Figure 48, the results also show that the factors of environmental risks (1.00) which were measured by five risk factors (R41 = 0.52; R42 = 0.63; R43 = 0.56; R44 = 0.51; R45 = 0.53) are most important factors which imperil performance. In addition, environmental performances (0.90) which were measured by three indicators (P11 = 0.56; P12 = 0.64; P13 = 0.68) are also influenced by supply chain risks more than other indices.

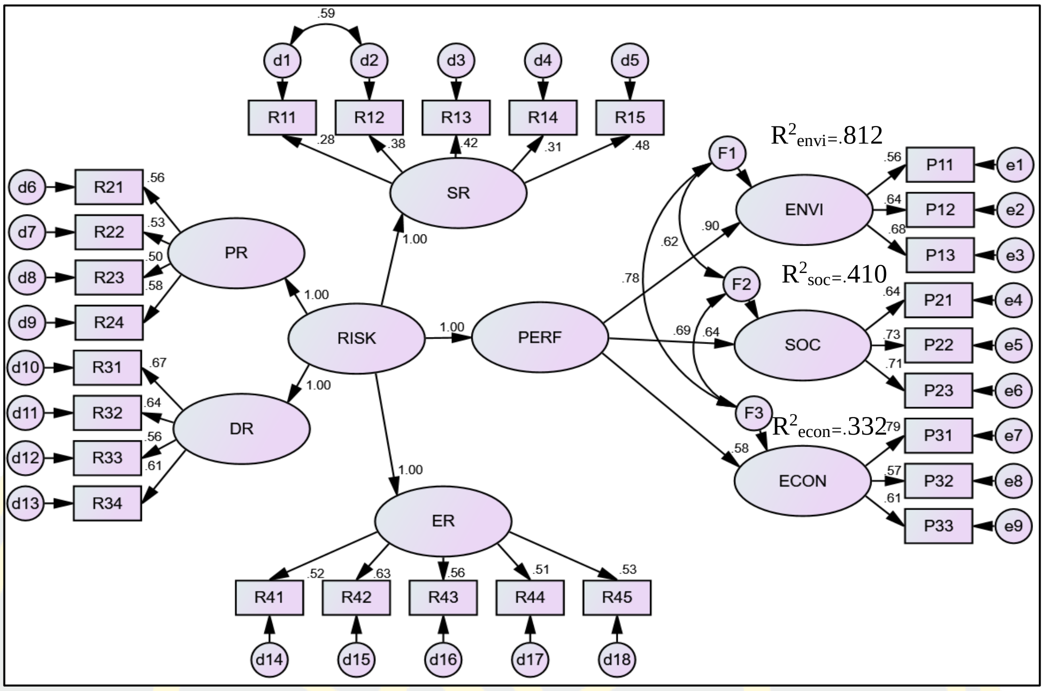

Figure 48 SEM for investigating risks that affect performance

Table 39 Results of testing for investigating risks that affect performance

	Risk			**Performance**			
	Totals effects (TE)	**Direct effects (DE)**	**Indirect effects (IE)**	**Totals effects (TE)**	**Direct effects (DE)**	**Indirect effects (IE)**	**R^2**
Supply risks	1.00	1.00	-	-	-	-	
Production risks	1.00	1.00	-	-	-	-	
Demand risks	1.00	1.00	-	-	-	-	
Environmental risks	1.00	1.00	-	-	-	-	
Performance	1.00	1.00	-	-	-	-	
Environmental performance	0.90	-	0.90	0.90	0.90	-	0.812

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Table 39 (Continued)

	Risk			Performance			
	Totals effects (TE)	**Direct effects (DE)**	**Indirect effects (IE)**	**Totals effects (TE)**	**Direct effects (DE)**	**Indirect effects (IE)**	**R^2**
Social performance	0.64	-	0.64	0.64	0.64	-	0.410
Economic performance	0.58	-	0.58	0.58	0.58	-	0.332
Chi-Square = 116.139; df = 205; Relative Chi-Square = 0.567; p-value = 1.000; RMSEA = 0.000; RMR = 0.026; GFI = 0.960; NFI = 0.951; TLI = 1.076							

Table 40 Estimates: critical ratio (C.R.)

			C.R.	**P**
Performance	<---	Risk	3.480	***
Environmental performance	<---	Performance		
Social performance	<---	Performance	5.614	***
Economic performance	<---	Performance	6.020	***
Supply risks	<---	Risk		
Production risks	<---	Risk	3.538	***
Demand risks	<---	Risk	3.691	***
Environmental risks	<---	Risk	3.483	***
Environmental performance	<-->	Social performance	2.681	**
Social performance	<-->	Economic performance	4.604	***
Environmental performance	<-->	Economic performance	3.515	***

Risk management for rice supply chain

From the research herein, we found the risk factors and highlighted the effects on rice supply chain performance. Thus, we can suggest risk management strategies to deal with the anticipated risks.

After interviewing and surveying 200 Cambodian farmers, the study results in Table 41 highlight the different risk management strategies for rice supply chains. In the overview, Table 41 indicates that most of the arithmetic mean (92 percent) is greater than or equal to 4 on the five-point Likert scale (4 = agree; 5 = strongly agree).

Based on the analysis of the risk management strategies for supply risks, providing an incentive to local seed producers and distributors has the highest mean value. Seeking alternative suppliers has the second highest mean value, followed by promoting contract farming and offering tax incentives to incentivize the importation of equipment and machinery, respectively. It is followed by using the system of “sharing-hand”: helping each other during the farming period; improving agricultural management practices, e.g., using direct seeding.

Based on the analysis of the risk management strategies for production risks, improving agricultural training has the highest mean value; followed by improving productivity by using high-yielding seeds and modern agricultural techniques; improving agricultural management practices for biological risks (e.g., better water management, improve seeds); improving the agricultural extension services to commune level; encouraging agricultural microfinance; encouraging and promoting policy on sustainable utilization of farming land, e.g., effective mapping; developing public policies and enforcing regarding sanitary and phytosanitary standards (e.g., food safety); using pesticide and fertilizer effectively; avoiding risky practices through organic farms; supporting and establishing Farmer Organization.

Based on the analysis of the risk management strategies for demand risks, the findings show that seeking alternative buyers is at the highest level; this is followed by conducting comprehensive research or study on national and international markets, potentially for rice, which can lead to the exploration of new opportunities; broadcasting and spreading research results to a wide range of rice producers; and improving transparency and market information, respectively.

The mean value for promoting contract farming with millers or buyers is 4.1, followed by improving warehouse management.

From the analysis of risk management strategies for environmental risks, the results illustrate that constructing and maintaining roads in the countryside (linking rice production areas to markets) is at the highest level. Improving agricultural know-how through training is the second highest; this is followed by developing irrigation; improving agricultural extension services to commune level; and managing the effects of Covid-19 on farmers by investing in vaccination programs, quarantine programs, more robust health systems, and advanced R & D; reducing electricity price and promoting electric power transmission to rural areas; adapting for climate change (e.g., agricultural diversification); purchasing insurance; aid or charity from government, international organization, and other donors, respectively.

Table 41 Risk management strategies for rice supply chains (n = 200)

Risk management strategies and relevant stakeholders		**Tools**	**$\bar{x}$**	**SD**	**s.e.**
Risk management strategies for supply risks					
Seek alternative suppliers’ (Farmers); (Related Stakeholders)	M1	RM; RC	4.1	0.8	0.1
Promote contract farming’ (MAFF); (Farmers); (Related Stakeholders)	M2	RT; RM	4.0	0.9	0.1
Provide the incentive to local seed producers and distributors’ (MAFF); (Related Stakeholders)	M3	RM	4.2	0.8	0.1
Use the system of “sharing-hand”: help each other during the farming period; improve agricultural management practices (e.g., using direct seeding)’ (Farmers); (Related Stakeholders)	M4	RM; RC	3.9	0.9	0.1

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Table 41 (Continued)

Risk management strategies and relevant stakeholders		Tools	x̄	SD	s. e.
Offer tax incentives to incentivize the imports of equipment and machinery' (MEF); (Related Stakeholders)	M5	RM	4.0	0.9	0.1
Risk management strategies for production risks					
Improve agricultural management practices for biological risks (e.g., better water management, improve seeds); improve the agricultural extension services to commune level' (Farmers); (MAFF); (Related Stakeholders)	M6	RM; RC	4.1	0.9	0.1
Encourage agricultural microfinance' (MEF); (NBC); (Related Stakeholders)	M7	RM	4.1	0.8	0.1
Encourage and promote policy on sustainable utilization of farming land (e.g., effective mapping)' (MLMUPC); (MAFF); (MOP: National Institute of Statistics of Cambodia-NIS); (Related Stakeholders)	M8	RM	4.1	0.9	0.1
Develop public policies and enforce regarding sanitary and phytosanitary standards (e.g., food safety); use pesticide and fertilizer effectively; avoid risky practices through organic farms' (MAFF); (MISTI); (MOH); (MOC); (Farmers); (Related Stakeholders)	M9	RC; RM; RA	4.1	0.9	0.1

Table 41 (Continued)

Risk management strategies and relevant stakeholders		**Tools**	**x̄**	**SD**	**s. e.**
Improve productivity by using high-yielding seed and modern agricultural techniques’ (MAFF); (Farmers); (Related Stakeholders)	M10	RM; RC	4.2	0.9	0.1
Support and establish Farmer Organization’ (MAFF); (Related Stakeholders)	M11	RM; RC	4.1	0.8	0.1
Improve agricultural training’ (MAFF); (Related Stakeholders)	M12	RM; RC	4.3	0.8	0.1
Risk management strategies for demand risks					
Conduct comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers’ (MOC); (MAFF); (Related Stakeholders)	M13	RM	4.2	0.8	0.1
Improve transparency and market information’ (MAFF); (Related Stakeholders)	M14	RM; RC	4.2	0.8	0.1
Promote contract farming with millers/buyers’ (MAFF); (Farmers); (Related Stakeholders)	M15	RT; RM	4.1	0.9	0.1
Improve warehouse management’ (Farmers); (Related Stakeholders)	M16	RM; RT	4.1	0.8	0.1

Table 41 (Continued)

Risk management strategies and relevant stakeholders		Tools	x̄	SD	s. e.
Seek alternative buyers’ (MAFF); (Farmers); (Related Stakeholders)	M17	RM; RC	4.3	0.9	0.1
Risk management strategies for environmental risks					
Adapt for climate change (e.g., agricultural diversification); purchase insurance; aid or charity from government, international organization, and other donors’ (Farmers); (Related Stakeholders)	M18	RT; RM; RC	3.9	0.8	0.1
Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)’ (MOWRAM); (MFAIC); (Farmers); (Related Stakeholders)	M19	RM; RC	4.2	0.8	0.1
Construct and maintain roads in the countryside (link rice production areas to markets)’ (MRD); (MPWT); (Related Stakeholders)	M20	RM; RC	4.4	0.8	0.1
Reduce electricity price and promote electric power transmission to rural areas’ (MISTI); (MME: Electricity Authority of Cambodia-EAC); (Related Stakeholders)	M21	RM; RC	4.1	0.9	0.1
Improve the agricultural extension services to commune level’ (MAFF); (Related Stakeholders)	M22	RM; RC	4.2	0.8	0.1

Table 41 (Continued)

Risk management strategies and relevant stakeholders		Tools	x̄	SD	s. e.
Improve agricultural know-how training’ (MAFF); (Related Stakeholders)	M23	RM; RC	4.3	0.7	0.1
Manage Covid-19 affects farmers by investing in the vaccination program, quarantine program, robust health systems, advanced R & D’ (MOH); (Related Stakeholders)	M24	RM; RC	4.2	0.8	0.1

RM, risk mitigation; RA, risk avoidance; RT, risk transfer; RC, risk coping

Risk management in the rice supply chain concerns issues of development efficiency and effectiveness, and is not just a matter related only to farmers. Notably, this study only focuses on farmers and the relevant stakeholders (e.g., government) who help farmers to manage risks in the rice supply chain. To ensure efficiency and effectiveness in risk management strategies, the following monitoring and coordinating actors are: 1) Ministry of Agriculture, Forestry and Fisheries (MAFF), 2) Ministry of Commerce (MOC), 3) Ministry of Economy and Finance (MEF), 4) Ministry of Foreign Affairs and International Cooperation (MFAIC), 5) Ministry of Health of Cambodia (MOH), 6) Ministry of Industry, Science, Technology and Innovation (MISTI), 7) Ministry of Land Management, Urban Planning and Construction (MLMUPC), 8) Ministry of Mines and Energy (MME), 9) Ministry of Planning (MOP), 10) Ministry of Public Works and Transport (MPWT), 11) Ministry of Rural Development (MRD), 12) Ministry of Water Resources and Meteorology (MOWRAM), 13) National Bank of Cambodia (NBC), 14) Farmers, and 15) Related Stakeholders, as shown in Table 41.

Participant A

“…We request that the government support us, notably better access to the market in terms of inputs and outputs…”

Participant B and Participant C

"…The government should teach us (villagers) about modern farming techniques to increase paddy rice productivity. We need training in agricultural diversification and effective financial management…"

Participant D

"…We need experts to train us on how to make organic fertilizer…"

Participant E

"…The government and microfinance institutions should provide loans to us with low-interest rates…", "…request higher rice prices…"

Participant F and Participant G

"…need ponds for rice farming…", "…request government to construct and maintain rural roads connecting rice production…", "…So, we request that the government support us…"

Participant H

"…need enough irrigation, lower costs of fertilizer and pesticides, and higher rice prices …"

Participant I

"…We want new agricultural techniques to increase yield, provide a good market for us, and help us relate to the biological risks…"

Participant J

"…We need training about modern agricultural know-how (including how to keep seeds), help with seed prioritization, need financial capital (loan) with a low-interest rate…"

Participant K

"...need good seeds, want to know how to make organic fertilizers, and increase miller availability in the commune ..."

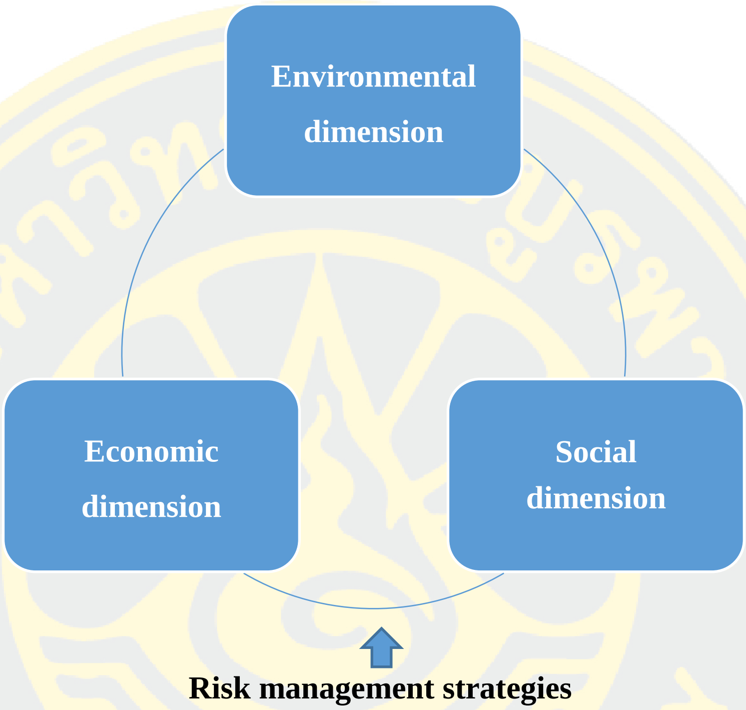

Figure 49 The contributing of the risk management strategies to sustainability

The risk management strategies contribute to sustainable rice supply chain management because the study shows that proposed risk management strategies address three dimensions (3Ds) of sustainability (Figure 49).

CHAPTER 5
SUMMARY OF RESEARCH FINDING, DISCUSSION, AND RECOMMENDATION

This research aimed to analyze the risks in the Cambodian rice supply chain. It involved three research questions: 1) what are the agricultural risk factors affecting the rice supply chain? 2) What are the effects of risk factors on rice supply chain performance, and 3) what actions should stakeholders take to manage the rice supply chain (RSC) risks?

The population for qualitative methodology and quantitative methodology in this scientific research are experts (n1 = 10) and farmers (n2 = 200) who are producing rice in Cambodia, respectively. Moreover, the researcher tried out 20 samples for the first pilot test and 30 samples for the second pilot test.

The research questionnaires used for this research are: 1) the research questionnaire for risk identification with the checklist, open-ended questions, other recommendations, and suggestions, 2) the research questionnaire for risk prioritization with the checklist, a five-level rating scale (vulnerable to risks and risk prioritization), other recommendations, and suggestions, and 3) research questionnaire for investigating risk effects and management strategies with the checklist, a five-level rating scale, other recommendations, and suggestions.

We requested five experts who earned Ph.D. degrees and have experience of more than five years to determine the IOC score. We tested variables using Chronbach’s Alpha (30 samples).

The researcher used descriptive and inferential statistics for data analysis, including arithmetic mean, sum, percentage, skewness, kurtosis, standard deviation, standard error, coefficient of variation (CV), and structural equation modeling (SEM), etc.

The importance of this research includes providing the knowledge connected with an enduring common practice, applying theories, making the generalizations, applying advanced methodology, evaluating a specific practice in Cambodia, and exploring new innovations for rice supply chain management.

In this chapter, the summary of research findings, discussion, and recommendations for the research utilization and future research include as below.

Summary of research findings

1. Risk identification of rice supply chain

There has been an attempt to identify risk factors in the rice supply chain in Cambodia, and the results indicated that farmers encountered 18 risk factors. Risks, which agricultural stakeholders encounter, can be organized into four categorizations, namely: supply risks, production risks, demand risks, and environmental risks (Table 42).

The arithmetic mean of all experts (n1 =10) was found to be 4.30 on the five-point Likert scale ranging from "strongly disagree" to "strongly agree".

The supply risks have five risk factors: (R11) rising costs of raw materials (fertilizer, pesticide, high yield seeds, fuel); (R12) rising costs of services (transportation, labor, interest rates or/ and credit, other agricultural services); (R13) lack of high yield seeds; (R14) lack of labor; (R15) lack of equipment and machinery.

The production risks have four risk factors: (R21) biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi); (R22) lack of financial capital; (R23) misuse of fertilizer or/ and pesticide; (R24) lack of agricultural know-how.

The demand risks have four risk factors: (R31) low prices of rice products; (R32) lack of market information; (R33) uncertainty of market demand for quantity; (R34) uncertainty of market demand for quality or/ and food safety requirements.

The environmental risks have five risk factors: (R41) natural disasters (flood, drought); (R42) lack of irrigation systems; (R43) lack or poor condition of basic infrastructure (roads, electricity); (R44) inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services); (R45) pandemic risks (Covid-19).

Table 42 Summary of risk prioritization in the rice supply chain

Risk	Var.	Probability (a)	Severity (b)	Expected loss scenarios (c=a*b)	Ranking
Lack of irrigation systems	R42	4.30	4.20	18.06	1
Misuse of fertilizer or/ and pesticide	R23	4.20	4.30	18.06	2
Rising costs of services	R12	4.40	4.00	17.60	3
Lack of agricultural know-how	R24	4.30	3.90	16.77	4
Low prices of rice products	R31	4.00	4.10	16.40	5
Lack or poor condition of basic infrastructure	R43	4.00	4.00	16.00	6
Uncertainty of market demand for quantity	R33	3.80	4.00	15.20	7
Lack of market information	R32	3.80	4.00	15.20	8
Biological risks	R21	4.00	3.80	15.20	9
Inadequate support from the government	R44	3.90	3.80	14.82	10
Rising costs of raw materials	R11	4.10	3.60	14.76	11
Lack of financial capital	R22	4.00	3.60	14.40	12
Natural disasters	R41	3.80	3.70	14.06	13
Covid-19	R45	3.50	3.50	12.25	14
Uncertainty of market demand for quality	R34	3.50	3.30	11.55	15
Lack of equipment and machinery	R15	3.60	3.10	11.16	16
Lack of labour	R14	3.30	3.30	10.89	17
Lack of high yield seeds	R13	3.40	3.20	10.88	18

2. Risk investigation of rice supply chain

The descriptive statistics of all risk factors and performances from the sample of 200 farmers were summarized below:

1. The supply risks were measured by five risk factors. The highest mean score was (R11) rising costs of raw materials; followed by (R12) rising costs of services; (R13) lack of high yield seeds; (R15) lack of equipment and machinery; (R14) lack of labor. The mean scores were 4.1, 3.9, 3.8, 3.8, and 3.6, respectively. Standard deviation values were 1.1, 1, 0.9, 1, and 1, respectively.

2. The production risks were measured by four risk factors. The highest mean score was (R24) lack of agricultural know-how; followed by (R21) biological risks; (R22) lack of financial capital; (R23) misuse of fertilizer or/ and pesticide. The mean scores were 4.1, 4, 4, and 3.9, respectively. Standard deviation values were 0.8, 0.9, 0.9, and 0.9, respectively.

3. The demand risks were measured by four risk factors. The highest mean score was (R31) low prices of rice products; followed by (R32) lack of market information; (R33) uncertainty of market demand for quantity; (R34) uncertainty of market demand for quality or/ and food safety requirements. The mean scores were 4.4, 4.3, 4.1, and 4.1, respectively. Standard deviation values were 1, 0.9, 0.9, and 0.8, respectively.

4. The environmental risks were measured by five risk factors. The highest mean score was (R42) lack of irrigation systems; followed by (R41) natural disasters; (R45) pandemic risks; (R44) inadequate support from the government; (R43) lack or poor condition of basic infrastructure. The mean scores were 4.2, 4.1, 4.1, 4, and 3.9, respectively. Standard deviation values were 0.8, 0.9, 1, 0.9, and 0.9, respectively.

5. The environmental performances were measured by three indicators. The highest mean score was (P13) the environmental pollutants; followed by (P11) the consumption rate of energy; (P12) the consumption rate of natural resources. The mean scores were 4, 3.9, and 3.8, respectively. Standard deviation values were 0.9, 0.8, and 0.7, respectively.

6. The social performances were measured by three indicators. The highest mean score was (P22) poverty; followed by (P23) farmers' knowledge; (P21) food

insecurity. The mean scores were 4.1, 4, and 3.7, respectively. Standard deviation values were 0.9, 0.8, and 0.8, respectively.

7. The economic performances were measured by three indicators. The highest mean score was (P33) return on investment; followed by (P31) rice yield of farming household; (P32) rice quality. The mean scores were 4, 3.9, and 3.8, respectively. Standard deviation values were 0.9, 0.9, and 0.8, respectively.

We investigated risks that affect rice supply chain performance (environmental, social, and economic aspects) using the structural equation model (SEM). The SEM of this study was a satisfactory fit for all indices, including (X^2/ df), p-value, RMSEA, RMR, GFI, NFI, and TLI. All statistical hypothesis testings were found to be significant. Especially, the results showed that rice supply chain performance was significantly affected by the rice supply chain risks.

3. Risk management for rice supply chain

We proposed appropriate solutions to mitigate, avoid, transfer, and cope with agricultural risks. The findings revealed that risk management strategies should include ex-ante and ex-post risk management strategies, as summarized below.

1. Based on the analysis of the risk management strategies for supply risks were;

1.1 Providing an incentive to local seed producers and distributors.

1.2 Seeking alternative suppliers.

1.3 Promoting contract farming.

1.4 Offering tax incentives to incentivize the importation of equipment and machinery.

1.5 Using the system of “sharing-hand”: helping each other during the farming period; improving agricultural management practices.

2. Based on the analysis of the risk management strategies for production risks were;

2.1 Improving agricultural training.

2.2 Improving productivity by using high-yielding seeds and modern agricultural techniques.

2.3 Improving agricultural management practices for biological risks; improving the agricultural extension services to commune level.

2.4 Encouraging agricultural microfinance.

2.5 Encouraging and promoting policy on sustainable utilization of farming land.

2.6 Developing public policies and enforcing regarding sanitary and phytosanitary standards; using pesticide and fertilizer effectively; avoiding risky practices through organic farms.

2.7 Supporting and establishing Farmer Organization.

3. Based on the analysis of the risk management strategies for demand risks were;

3.1 Seeking alternative buyers.

3.2 Conducting comprehensive research or study on national and international markets; broadcasting and spreading research results to a wide range of rice producers.

3.3 Improving transparency and market information.

3.4 Promoting contract farming with millers or buyers.

3.5 Improving warehouse management.

4. From the analysis of risk management strategies for environmental risks were;

4.1 Constructing and maintaining roads in the countryside.

4.2 Improving agricultural know-how through training.

4.3 Developing irrigation.

4.4 Improving agricultural extension services to commune level.

4.5 Managing the effects of Covid-19 on farmers by investing in vaccination programs, quarantine programs, more robust health systems, and advanced R & D.

4.6 Reducing electricity price and promoting electric power transmission to rural areas.

4.7 Adapting for climate change; purchasing insurance; aid or charity from government, international organization, and other donors.

The monitoring and coordinating actors (as demonstrated in table 41) are; 1) Ministry of Agriculture, Forestry and Fisheries (MAFF), 2) Ministry of Commerce (MOC), 3) Ministry of Economy and Finance (MEF), 4) Ministry of Foreign Affairs and International Cooperation (MFAIC), 5) Ministry of Health of Cambodia (MOH), 6) Ministry of Industry, Science, Technology and Innovation (MISTI), 7) Ministry of Land Management, Urban Planning and Construction (MLMUPC), 8) Ministry of Mines and Energy (MME), 9) Ministry of Planning (MOP), 10) Ministry of Public Works and Transport (MPWT), 11) Ministry of Rural Development (MRD), 12) Ministry of Water Resources and Meteorology (MOWRAM), 13) National Bank of Cambodia (NBC), 14) Farmers, and 15) Related Stakeholders.

Discussion of research findings

The research findings are discussed based on three specific objectives which cover: 1) identifying the agricultural risk factors in the rice supply chain, 2) investigating risk factors that affect rice supply chain performance, and 3) proposing risk management strategies in the sustainable rice supply chain management. Lam et al. (2015) demonstrated supply chain risk management (SCRM) tasks, including identifying risks on the demand and supply sides of the chain, assessing risks based on value chain analysis, and managing the rice supply chain risks. Rohmah et al. (2015) assessed risks in terms of probability of occurrence, severity effect, and the likelihood of detection in the organic rice supply chain. Zandi et al. (2020) showed SCRM tasks, including identifying risks, assessing risks via three factors (severity, occurrence, and detectability), and managing risks in the agricultural supply chain (ASC). Linn and Maenhout (2019) aimed to identify the sources of uncertainty, investigate environmental uncertainty on the performance of the rice supply chain, and propose risk management strategies. Xu et al. (2021) studied by identifying the factors that affect the resilience and managing risks in the agricultural supply chain regarding water resources use.

1. Risk identification of rice supply chain

While previous studies have categorized risks differently, we consolidated them into four classifications. The results illustrate that the farm households face 18 risk factors. We consolidate 18 risk factors into four classifications: supply risks, production risks, demand risks, and environmental risks. World Bank (2016) categorized risks into market, production, and enabling environmental risks. Jaffee et al. (2008, 2010) classified the main risks facing agricultural supply chains into eight groups, including weather-related risks, natural disasters (encompassing extreme weather events), environmental and biological risks, market-related risks, infrastructural and logistical risks, operational and management risks, institutional and public policy risks, and political risks. Komarek et al. (2019) consolidated the five primary types of risk in agriculture into institutional risk, personal risk, production risk, market risk, and financial risk. Behzadi et al. (2018) organized risks into supply-side and demand-side risks. Nto et al. (2014) grouped risks in rice production in Nigeria into rice-technical risk, market risk, financial risk, political risk, and social risk. Lam et al. (2015) categorized the Hong Kong rice supply chain risks into natural disasters and weather-related risk; environmental and biological risk; market-related risk; infrastructural and logistical risk; operational and managerial risk; institutional and government policy risk; order of risk magnitude. Linn and Maenhout (2019) classified risks in Myanmar into supply uncertainty, demand uncertainty, process uncertainty, planning and controlling uncertainty, competitor uncertainty, the uncertainty of the grantee price from public regulation, new government uncertainty, and climate uncertainty. Rohmah et al. (2015) consolidated risks in the organic rice supply chain in MUTOS Selolima into the risk of product declined; risk of damage while storage; risk of demand changing; risk of machine damage while the process; risk of damage during the process; risk of processing delays; risk of supply delays; risk of containing chemical contaminants; risk of quality incapability; risk of competitor presence; risk of shortage of stock; risk of product contamination during the process; risk of damage or loss of quality; risk of goods return. World Bank (2011) identified risks in the rice sector in Guyana according to key rice industry stakeholders and the climatic data from the past 20 years. They included production risks; market risks (including increasing transportation costs); other risks (regulatory risks, preferential-market-access erosion, and inaccessibility to dam roads). Risks identification relied on the potential to produce losses and the likelihood of such events occurring.

2. Risk investigation of rice supply chain

The supply risks were measured by five risk factors. The highest mean score was (R11) rising costs of raw materials; followed by (R12) rising costs of services; (R13) lack of high yield seeds; (R15) lack of equipment and machinery; (R14) lack of labor. The mean scores were 4.1, 3.9, 3.8, 3.8, and 3.6, respectively. Standard deviation values were 1.1, 1, 0.9, 1, and 1, respectively. These results build on existing evidence of risk factors in Cambodia, including rising costs of raw materials (Dalgliesh et al., 2016; Mishra, Bairagi, et al., 2018); rising costs of services (Ches & Yamaji, 2016; Martin et al., 2021); lack of high yield seeds (Montgomery et al., 2017; Turner et al., 2017); lack of equipment and machinery (Kea et al., 2016; Mao et al., 2014); lack of labor (Iwahashi et al., 2021; Martin, 2017; Seng, 2014; Xangsayasane et al., 2019).

The production risks were measured by four risk factors. The highest mean score was (R24) lack of agricultural know-how; followed by (R21) biological risks; (R22) lack of financial capital; (R23) misuse of fertilizer or/ and pesticide. The mean scores were 4.1, 4, 4, and 3.9, respectively. Standard deviation values were 0.8, 0.9, 0.9, and 0.9, respectively. These results fit with the previous studies in Cambodia, including lack of agricultural know-how (Castilla et al., 2019; Chhun et al., 2019; Flor, Maat, Hadi, Then, et al., 2019; Grunfeld & Ng, 2013); biological risks (Kea et al., 2016; Mao et al., 2014; Wokker et al., 2014); lack of financial capital (Kea et al., 2016; Mao et al., 2014; Mishra, Bairagi, et al., 2018; Montgomery et al., 2017); misuse of fertilizer or/ and pesticide (Flor et al., 2018; Flor, Maat, Hadi, Kumar, et al., 2019; Schreinemachers et al., 2015).

The demand risks were measured by four risk factors. The highest mean score was (R31) low prices of rice products; followed by (R32) lack of market information; (R33) uncertainty of market demand for quantity; (R34) uncertainty of market demand for quality or/ and food safety requirements. The mean scores were 4.4, 4.3, 4.1, and 4.1, respectively. Standard deviation values were 1, 0.9, 0.9, and 0.8, respectively. The data contributes to a clearer understanding of risk factors in Cambodia. Also, previous studies showed: low prices of rice products (Horita, 2016; Kong & Castella, 2021); lack of market information (Mao et al., 2014; Mishra, Bairagi, et al., 2018); uncertainty of market demand for quantity (Horita, 2016); uncertainty of market demand for quality or/ and food safety requirements (Horita, 2016).

The environmental risks were measured by five risk factors. The highest mean score was (R42) lack of irrigation systems; followed by (R41) natural disasters;

(R45) pandemic risks; (R44) inadequate support from the government; (R43) lack or poor condition of basic infrastructure. The mean scores were 4.2, 4.1, 4.1, 4, and 3.9, respectively. Standard deviation values were 0.8, 0.9, 1, 0.9, and 0.9, respectively. Also, previous research in Cambodia illustrated risk factors - lack of irrigation systems (Schuch et al., 2021; Sithirith, 2017); natural disasters (Bairagi et al., 2020; Dany et al., 2015; Kong & Castella, 2021); pandemic risks (Hossain, 2018a); inadequate support from the government (Dany et al., 2015; Schreinemachers et al., 2015); lack or poor condition of basic infrastructure (Kea et al., 2016; Mao et al., 2014; Nguyen et al., 2019).

Sustainable performance consists of three latent variables: environmental, social, and economic performance. First, the environmental performances were measured by three indicators. The highest mean score was (P13) the environmental pollutants; followed by (P11) the consumption rate of energy; (P12) the consumption rate of natural resources. The mean scores were 4, 3.9, and 3.8, respectively. Standard deviation values were 0.9, 0.8, and 0.7, respectively. Second, the social performances were measured by three indicators. The highest mean score was (P22) poverty; followed by (P23) farmers' knowledge; (P21) food insecurity. The mean scores were 4.1, 4, and 3.7, respectively. Standard deviation values were 0.9, 0.8, and 0.8, respectively. Third, the economic performances were measured by three indicators. The highest mean score was (P33) return on investment; followed by (P31) rice yield of farming household; (P32) rice quality. The mean scores were 4, 3.9, and 3.8, respectively. Standard deviation values were 0.9, 0.9, and 0.8, respectively. Also, previous studies has focused on the dimension of environmental performance, the dimension of social performance, and the dimension of economic performance (Chhay et al., 2017; Demont & Rutsaert, 2017; Krishnan et al., 2020; Liu et al., 2020; Okpiaifo et al., 2020; Röder et al., 2020; Tran et al., 2021; Zeweld et al., 2019).

As discussed in Chapter 2 (see the literature), many studies have been conducted in developed and developing countries. However, a few academic studies are relevant to this study topic (case study in Cambodia); this discussion cannot provide in-depth insights into Cambodia in line with the hypotheses. We investigated risks that affect rice supply chain performance (environmental, social, and economic aspects) using the structural equation model (SEM). The SEM of this study was a satisfactory fit for all indices, including (X^2/ df), p-value, RMSEA, RMR, GFI, NFI, and TLI. Finally, we concluded the results that rice supply chain performance was significantly affected by the rice supply chain risks. This finding is as same as that by Linn and Maenhout (2019) who studied in Myanmar and concluded that the rice supply chain performance is significantly impacted by uncertainty.

3. Risk management for rice supply chain

This study demonstrates that the four groups of risk management strategies for the rice supply chain are created, representing two different approaches to mitigate, avoid, transfer, and cope with agricultural risks, i.e., ex-ante and ex-post risk management strategies. World Bank (2016) demonstrated that a practical way to identify solutions is by categorizing potential risk management strategies into three classifications: coping, mitigation, and risk transfer. Jaffee et al. (2008, 2010) illustrated approaches to risk management include ex-ante strategies (risk mitigation, risk reduction, risk retention, risk-sharing or transfer, risk avoidance) or ex-post strategies (risk coping). Good management practices are usually also good risk-management practices and consist of coping-transfer-mitigation with the risks (World Bank, 2011).

Research limitations and recommendations

1. Research limitations

With regard to study limitations, the following aspects should be noted. This study pays attention to the RSC in Cambodia exclusively. Because of financial constraints, we only focused on farmers and relevant stakeholders who help farmers. Although these research findings are consistent with other studies, they cannot generalize about the whole of Cambodia and other countries. Thus, the results of this research can only depict the context of the research area.

2. Recommendations for the research utilization

A few recommendations could be put forward to help develop the Cambodian rice supply chain in several ways:

1. Cambodian farmers need to pay additional attention to risk identification, risk investigation, risk management, and the effective application of this academic study into practical activities.

2. The Royal Government of Cambodia (RGC), a significant actor, should continue to make policies, prepare plans, and develop strategies as proposed by researchers with respect to the risk management strategies (Table 41). Moreover, risk management interventions can be associated with the public stakeholders, such as government policy, public investment, agricultural training, and extension services.

3. NGOs should continue to play their part in helping to support the supply chain. They can provide training, especially to create development programs or projects to find optimal ways to improve the current problems related to the supply chain.

4. Even though this study focuses only on farmers, further coordination may be needed from commercial institutions. When commercial players coordinate efficiently, they are able to help farmers and protect their interests sustainably.

Risk management in the rice supply chain concerns issues of development efficiency and effectiveness, and is not just a matter related only to farmers. To ensure efficiency and effectiveness in risk management strategies, the following monitoring and coordinating actors are: 1) Ministry of Agriculture, Forestry and Fisheries (MAFF), 2) Ministry of Commerce (MOC), 3) Ministry of Economy and Finance (MEF), 4) Ministry of Foreign Affairs and International Cooperation (MFAIC), 5) Ministry of Health of Cambodia (MOH), 6) Ministry of Industry, Science, Technology and Innovation (MISTI), 7) Ministry of Land Management, Urban Planning and Construction (MLMUPC), 8) Ministry of Mines and Energy (MME), 9) Ministry of Planning (MOP), 10) Ministry of Public Works and Transport (MPWT), 11) Ministry of Rural Development (MRD), 12) Ministry of Water Resources and Meteorology (MOWRAM), 13) National Bank of Cambodia (NBC), 14) Farmers, and 15) Related Stakeholders.

3. Recommendations for future research

1. Scholars could also adapt this study by applying to different stakeholders in the same or other sectors and the same or other countries. For example, even though this study only focuses on farmers and relevant stakeholders (e.g., government) who help farmers, scholars might adapt to another stakeholder. The multiple stakeholders in the rice supply chain are farmers, millers, exporters,

traders, and government agencies with support services from commercial banks or MFIs, input suppliers (seeds, fertilizers, and chemicals), distributors, and logistics agents interacting with each other. Collaboration and joint ownership with every group of stakeholders are crucial. Risks can also extend over the inbound stage and the outbound stage. Thus, they can impact farmers and the multiple stakeholders in the supply chain.

2. Next research should prioritize the risk management strategies (See Jaffee et al., 2008, 2010).

3. Future research should have a larger sample size and a more extensive research area. Thus, further study can generalize about the whole of Cambodia.

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APPENDICES

APPENDIX A

RELEVANT MAPS AND INFORMATION

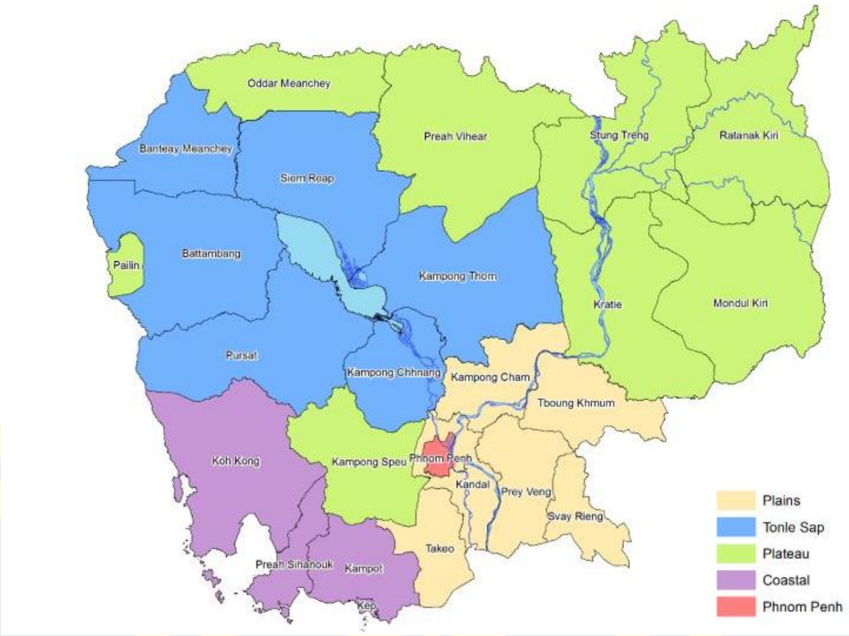

Figure A1 Map of ecological zone in Cambodia
(World Food Programme, 2019a)

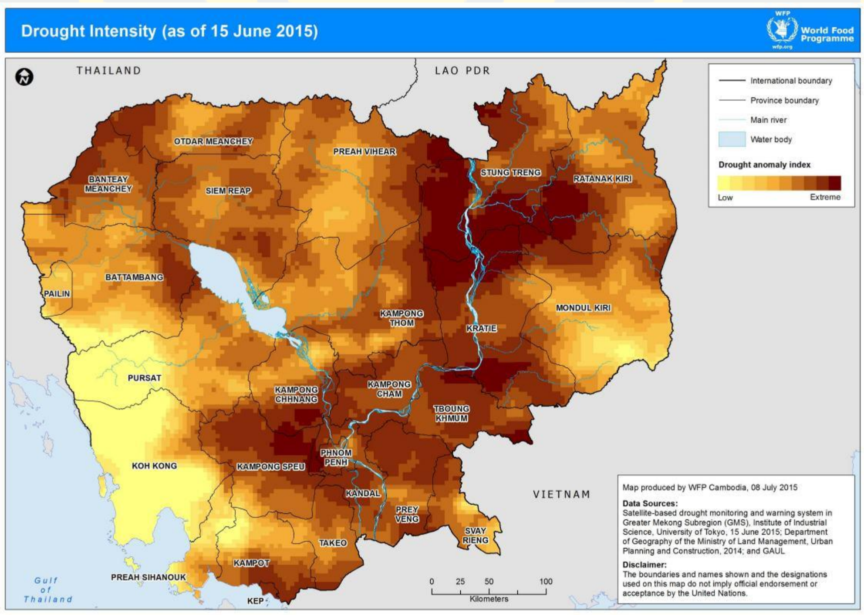

Figure A2 Map of drought intensity in Cambodia as of 15 June 2015
(World Food Programme, 2019a)

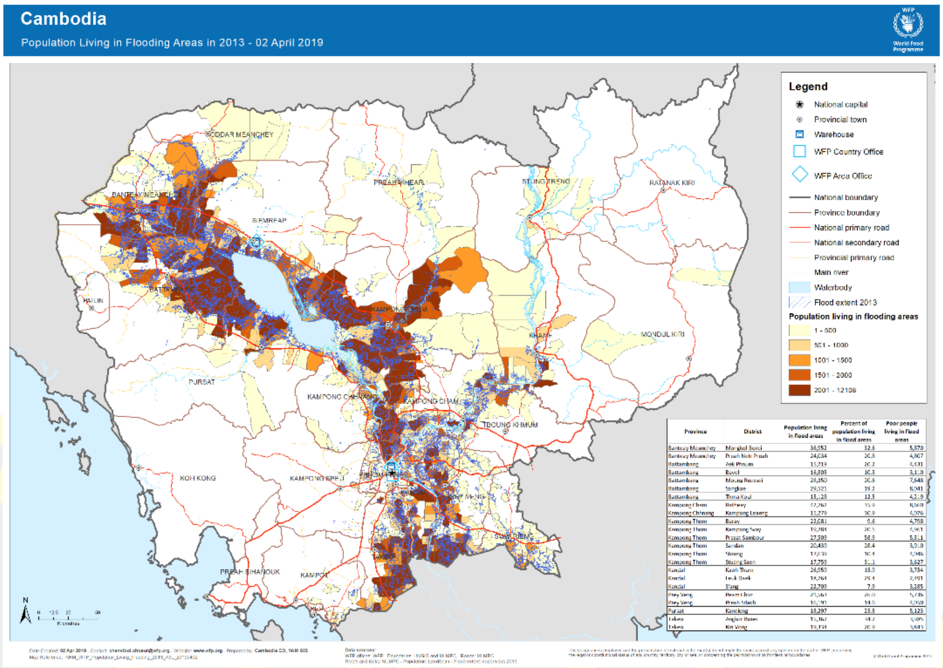

Figure A3 Map of Cambodian living in flooding areas (2013 - 02 April 2019) (World Food Programme, 2019b)

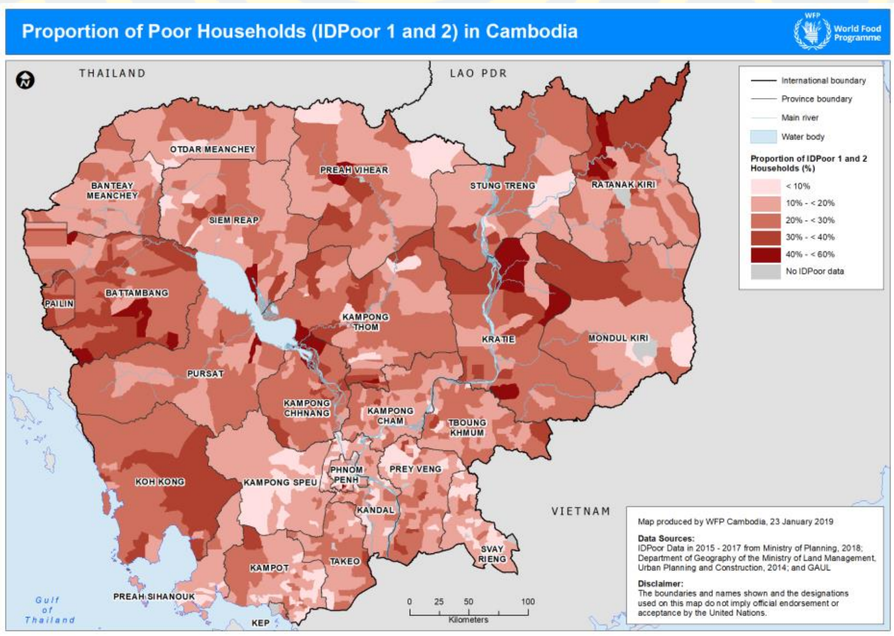

Figure A4 Map of poor households in Cambodia (Publication Date 2019) (World Food Programme, 2019c)

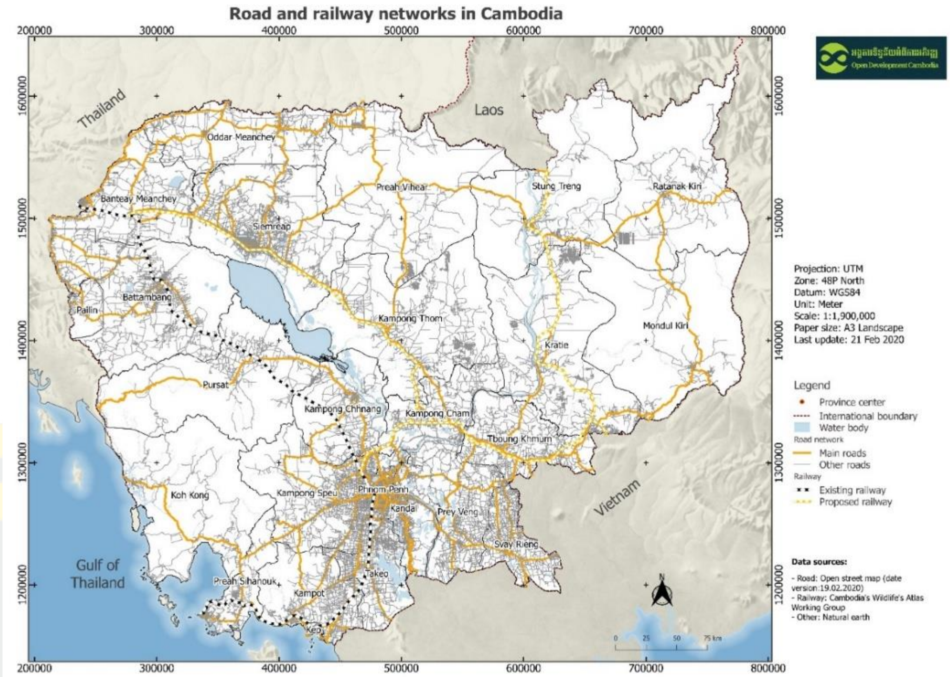

Figure A5 Map: networks of road and railway in Cambodia from 2012 to 2020 (Open Development Cambodia, 2020)

Figure A6 Soil fertility map in Cambodia- modified 2019
(Open Development Cambodia, 2019b)

Table A1 102 communes and 14 districts Battambang Province

Battambang province consists of 102 communes and 14 districts		
No	**Name of communes**	**Code**
	Banan	
1	Kantueu Muoy	020101
2	Kantueu Pir	020102
3	Bay Damram	020103
4	Chheu Teal	020104
5	Chaeng Mean Chey	020105
6	Phnum Sampov	020106
7	Snoeng	020107
8	Ta Kream	020108
	Thma Koul	
9	Ta Pung	020201
10	Ta Meun	020202
11	Ou Ta Ki	020203
12	Chrey	020204
13	Anlong Run	020205
14	Chrouy Sdau	020206
15	Boeng Pring	020207
16	Kouk Khmum	020208
17	Bansay Traeng	020209
18	Rung Chrey	020210
	Krong Battambang	
19	Sangkat Tuol Ta Aek	020301
20	Sangkat Preaek Preah Sdach	020302
21	Sangkat Rotanak	020303
22	Sangkat Chamkar Samraong	020304
23	Sangkat Sla Kaet	020305

Battambang province consists of 102 communes and 14 districts		
No	Name of communes	Code
24	Sangkat Kdol Daun Teav	020306
25	Sangkat Ou Mal	020307
26	Sangkat Voat Kor	020308
27	Sangkat Ou Char	020309
28	Sangkat Svay Pao	020310
	Bavel	
29	Bavel	020401
30	Khnach Romeas	020402
31	Lvea	020403
32	Prey Khpos	020404
33	Ampil Pram Daeum	020405
34	Kdol Ta Haen	020406
35	Khlang Meas	020407
36	Boengbram	020408
	Aek Phnum	
37	Preaek Norint	020501
38	Samraong Knong	020502
39	Preaek Khpob	020503
40	Preaek Luong	020504
41	Peam Aek	020505
42	Prey Chas	020506
43	Kaoh Chiveang	020507
	Moung Ruessei	
44	Moung Ruessei	020601
45	Kear	020602
46	Prey Svay	020603
47	Ruessei Krang	020604
48	Chrey	020605

Battambang province consists of 102 communes and 14 districts		
No	Name of communes	Code
49	Ta Loas	020606
50	Kakaoh	020607
51	Prey Touch	020608
52	Robas Mongkol	020609
	Rotonak Mondol	
53	Sdau	020701
54	Andaeuk Haeb	020702
55	Phlov Meas	020703
56	Traeng	020704
57	Reaksmey Sangha	020705
	Sangkae	
58	Anlong Vil	020801
59	Norea	020802
60	Ta Pun	020803
61	Roka	020804
62	Kampong Preah	020805
63	Kampong Prieng	020806
64	Reang Kesei	020807
65	Ou Dambang Muoy	020808
66	Ou Dambang Pir	020809
67	Vaot Ta Moem	020810
	Samlout	
68	Ta Taok	020901
69	Kampong Lpov	020902
70	Ou Samrel	020903
71	Sung	020904
72	Samlout	020905
73	Mean Chey	020906

Battambang province consists of 102 communes and 14 districts		
No	Name of communes	Code
74	Ta Sanh	020907
	Sampov Lun	
75	Sampov Lun	021001
76	Angkor Ban	021002
77	Ta Sda	021003
78	Santepheap	021004
79	Serei Mean Chey	021005
80	Chrey Seima	021006
	Phnom Proek	
81	Phnom Proek	021101
82	Pech Chenda	021102
83	Chak Krey	021103
84	Barang Thleak	021104
85	Ou Rumduol	021105
	Kamrieng	
86	Kamrieng	021201
87	Boeung Reang	021202
88	Ou Da	021203
89	Trang	021204
90	Ta Saen	021205
91	Ta Krey	021206
	Koas Krala	
92	Thipakdei	021301
93	Kaos Krala	021302
94	Hab	021303
95	Preah Phos	021304
96	Doun Ba	021305
97	Chhnal Mean	021306

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Battambang province consists of 102 communes and 14 districts		
No	**Name of communes**	**Code**
	Rukhak Kiri	
98	Preaek Chik	021401
99	Prey Tralach	021402
100	Mokrear	021403
101	Sdok Brovek	021404
102	Basak	021405
Total is 102 communes and 14 districts		

Authors' own acquiring from "Financial management information system (FMIS)" (2019)

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APPENDIX B

THE LIST OF EXPERTS

A list of experts who examine IOC and the questionnaires

1. Dr. SARAWUT JANSUWAN, Assistant Professor, Department of Logistics Management, National Institute of Development Administration (NIDA), Thailand

2. Dr. JUTHATHIP SURARAKSA, Assistant Professor, Faculty of Logistics, Burapha University, Thailand

3. Dr. PAO SREAN, Dean, Faculty of Agriculture and Food Processing, National University of Battambang, Cambodia

4. Dr. SOKVIBOL KEA, Lecturer, Faculty of Sociology and Community Development, National University of Battambang, Cambodia

5. Dr. LYNA PRAK, Lecturer, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Thailand

A list of experts who examine the suitability of the conceptual framework, the first draft, and the research

No	Name	Title
1	Associate Professor Dr. Nakorn Indra-Payoong	Dean, Faculty of Logistics, Burapha University, Thailand
2	Assistant Professor Dr. Thitima Wonginta	Assistant Professor, Faculty of Logistics, Burapha University, Thailand
3	Assistant Professor Dr. Chompoonut Amchang	Assistant Professor, Faculty of Logistics, Burapha University, Thailand
4	Dr. Saowanit Lekhavat	Lecturer, Faculty of Logistics, Burapha University, Thailand
5	Assistant Professor Dr. Sarawut Jansuwan	Assistant Professor, Department of Logistics Management, National Institute of Development Administration (NIDA), Thailand
6	Associate Professor Dr. Sarawut Luksanato	Associate Professor, Faculty of Logistics, Burapha University, Thailand
7	Assistant Professor Dr. Juthathip Suraraksa	Assistant Professor, Faculty of Logistics, Burapha University, Thailand
8	Assistant Professor Dr. Pairoj Raothanachonkun	Assistant Professor, Faculty of Logistics, Burapha University, Thailand
9	Assistant Professor Dr. Thanyaphat Muangpan	Assistant Professor, Faculty of Logistics, Burapha University, Thailand

APPENDIX C

RESEARCH QUESTIONNAIRE

มหาวิทยาลัยบูรพา
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Research questionnaire for risk identification
(Risk analysis of rice supply chain in Cambodia)

Introduction:

1. This questionnaire is employed to collect the primary data for the study entitled: "Risk analysis of rice supply chain in Cambodia".

2. This questionnaire is prepared to meet the requirement for identifying the risk factors, which is to confirm with literature view and add more risk factors in the rice supply chain in Cambodia.

3. This questionnaire is separated into three parts:

Part 1: Respondents' profile using the checklist, which contains sex, marital status, age, educational level, and professional experience.

Part 2: Risk identification with open-ended question.

Part 3: Other recommendations and suggestions.

4. The data, which got from this questionnaire, is employed to analyze the overall aspects of risk in the rice supply chain for academic purposes only; there is no way to impact neither the respondents nor their position. Your contribution to this study is voluntary and anonymous. We will not reveal your personal information that could lead to the identification of any individual or your organization to any other external parties or research project without your authorization. Therefore, please kindly answer all questions.

If you have any questions related to this questionnaire or need assistance in responding to this questionnaire, please kindly contact Mr. Bunhorng Rath, email: rath.bunhorng@gmail.com.

Thank you so much for your participation and best regards,

Mr. Bunhorng Rath
Doctor of Philosophy Student in Logistics and Supply Chain Management
Faculty of Logistics, Burapha University

QRE ID			

Part I: Personal profile

Instruction: please tick (✓) in the box (☐) that is true for you and complete in the space as required:

Q1. Sex	☐	1. Male
	☐	2. Female
Q2. Marital status	☐	1. Single
	☐	2. Married
	☐	3. Widow/ widower
Q3. Age	☐	1. Under 30
	☐	2. 30-39 years old
	☐	3. 40-49 years old
	☐	4. Older than to 50 years
Q4. Educational level	☐	1. Never go to school
	☐	2. Preschool
	☐	3. Primary school
	☐	4. Junior high school
	☐	5. Senior high School
	☐	6. Bachelor
	☐	7. Other (e.g. informal education), specify………………………..
Q5. Experience/ working related to rice farming	☐	1. Less than 5 years
	☐	2. 5-10 years
	☐	3. 11-15 years
	☐	4. 16-20 years
	☐	5. More than 20 years

Part II: Risk identification

Instruction: please answers the open-ended question in the space as required:

Q6. What are the risk factors in the rice supply chain?

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Part III: Recommendations and suggestions

Q7. More comments, suggestions, or perception?

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Thank you very much for answering the questions!

Research questionnaire for risk prioritization

(Risk analysis of rice supply chain in Cambodia)

Introduction:

1. This questionnaire is employed to collect the primary data for the study entitled: "Risk analysis of rice supply chain in Cambodia".

2. This questionnaire is prepared to meet the requirement for prioritizing the risk factors in the rice supply chain in Cambodia.

3. This questionnaire is separated into three parts:

Part 1: Respondents' profile using the checklist, which contains sex, marital status, age, educational level, the position of respondent, and professional experience.

Part 2: Risk prioritization with a five-level rating scale.

Part 3: Other recommendations and suggestions.

4. The data, which got from this questionnaire, is employed to analyze the overall aspects of risk in the rice supply chain for academic purposes only; there is no way to impact neither the respondents nor their position. Your contribution to this study is voluntary and anonymous. We will not reveal your personal information that could lead to the identification of any individual or your organization to any other external parties or research project without your authorization. Therefore, please kindly answer all questions.

If you have any questions related to this questionnaire or need assistance in responding to this questionnaire, please kindly contact Mr. Bunhorng Rath email: rath.bunhorng@gmail.com.

Thank you so much for your participation and best regards,

Mr. Bunhorng Rath

Doctor of Philosophy Student in Logistics and Supply Chain Management

Faculty of Logistics, Burapha University

QRE ID			

Part I: Experts' profile

Instruction: please tick (✓) in the box (☐) that is true for you and complete in the space as required:

Q1. Sex	☐	1. Male
	☐	2. Female
Q2. Marital status	☐	1. Single
	☐	2. Married
	☐	3. Widow/ widower
Q3. Age	☐	1. Under 30
	☐	2. 30-39 years old
	☐	3. 40-49 years old
	☐	4. Older than to 50 years
Q4. Educational level	☐	1. Master
	☐	2. Doctor of Philosophy
	☐	3. Specify………
Q5. Position of the respondent	☐	1. Farming Expert
	☐	2. Professor/ Lecturer-holding Ph.D.
	☐	3. Others, specify………………
Q6. Professional experience/ working related to rice supply chain	☐	1. Less than 5 years
	☐	2. 5-10 years
	☐	3. 11-15 years
	☐	4. 16-20 years
	☐	5. More than 20 years
Q7. In general, do you think your rice supply chain as vulnerable to risks? **Note**: vulnerability to risky event relied on expected loss (expected loss scenarios=likelihood *severity)	☐	1. Strongly disagree
	☐	2. Disagree
	☐	3. Neutral
	☐	4. Agree
	☐	5. Strongly agree

Part II: Risk prioritization

Instruction: please complete and tick (✓) in the box (☐) from 1 to 5 that most closely matches the risk prioritization in terms of “likelihood” for the rice supply chain in Cambodia.

5 = “strongly agree” refers to the reality that strongly suitable to the likelihood of occurrence

4 = “agree” refers to the reality that very suitable to the likelihood of occurrence

3 = “neutral” refers to the reality that moderately suitable to the likelihood of occurrence

2 = “disagree” refers to the reality that less suitable to the likelihood of occurrence

1 = “strongly disagree” refers to the reality that very less suitable to the likelihood of occurrence

Instruction: please complete and tick (✓) in the box (☐) from 1 to 5 that most closely matches the risk prioritization in terms of “severity of the effect” for the rice supply chain in Cambodia.

5 = “strongly agree” refers to the reality that strongly suitable to the severity of effect

4 = “agree” refers to the reality that very suitable to the severity of effect

3 = “neutral” refers to the reality that moderately suitable to the severity of effect

2 = “disagree” refers to the reality that less suitable to the severity of effect

1 = “strongly disagree” refers to the reality that very less suitable to the severity of effect

Q8. Supply risks

The factors of supply risks		Likert scale									
		Likelihood					Severity of effects				
8.1	Rising costs of raw materials (fertilizer, pesticide, high yield seeds)	1	2	3	4	5	1	2	3	4	5
8.2	Rising costs of services (transportation, labor, interest rates or/ and credit)	1	2	3	4	5	1	2	3	4	5
8.3	Lack of high yield seeds	1	2	3	4	5	1	2	3	4	5
8.4	Lack of labor	1	2	3	4	5	1	2	3	4	5
8.5	Lack of equipment and machinery	1	2	3	4	5	1	2	3	4	5
Suggestion and comments:											

Q9. Production risks

The factors of production risks		Likert scale									
		Likelihood					Severity of effects				
9.1	Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)	1	2	3	4	5	1	2	3	4	5
9.2	Lack of financial capital	1	2	3	4	5	1	2	3	4	5
9.3	Misuse of fertilizer or/ and pesticide	1	2	3	4	5	1	2	3	4	5
9.4	Lack of agricultural know-how	1	2	3	4	5	1	2	3	4	5
Suggestion and comments:											

Q10. Demand risks

The factors of demand risks		Likert scale									
		Likelihood					Severity of effects				
10.1	Low prices of rice products	1	2	3	4	5	1	2	3	4	5
10.2	Lack of market information	1	2	3	4	5	1	2	3	4	5
10.3	Uncertainty of market demand for quantity	1	2	3	4	5	1	2	3	4	5
10.4	Uncertainty of market demand for quality or/ and food safety requirements	1	2	3	4	5	1	2	3	4	5
Suggestion and comments:											

Q11. Environmental risks

The factors of environmental risks		Likert scale									
		Likelihood					Severity of effects				
11.1	Natural disasters (flood, drought)	1	2	3	4	5	1	2	3	4	5
11.2	Lack of irrigation systems	1	2	3	4	5	1	2	3	4	5
11.3	Lack or poor condition of basic infrastructure (roads, electricity)	1	2	3	4	5	1	2	3	4	5
11.4	Inadequate support from the government (lack of agricultural know-how training or/ and lack of public extension services)	1	2	3	4	5	1	2	3	4	5
11.5	Pandemic risks (Covid-19)	1	2	3	4	5	1	2	3	4	5
Suggestion and comments:											

Part III: Recommendations and suggestions

More comments, suggestions, or perception?

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Thank you very much for answering the questions!

Research questionnaire for investigating risk effects and management strategies (Risk analysis of rice supply chain in Cambodia)

Introduction:

1. This questionnaire is employed to collect the primary data for the study entitled: “Risk analysis of rice supply chain in Cambodia”.

2. This questionnaire is prepared to meet the requirement for investigating risk factors that affect to rice supply chain performance in Cambodia and focusing on risk management strategies.

3. This questionnaire is separated into three parts:

Part 1: Respondents’ profile using the checklist, which contains sex, marital status, age, educational level, and professional experience.

Part 2: Investigating risk factors that affect rice supply chain performance and focusing on risk management strategies, with a five-level rating scale.

Part 3: Other recommendations and suggestions.

4. The data, which got from this questionnaire, is employed to analyze the overall aspects of risk in the rice supply chain for academic purposes only; there is no way to impact neither the respondents nor their position. Your contribution to this study is voluntary and anonymous. We will not reveal your personal information that could lead to the identification of any individual or your organization to any other external parties or research project without your authorization. Therefore, please kindly answer all questions and then return this questionnaire in a confidential envelope.

If you have any questions related to this questionnaire or need assistance in responding to this questionnaire, please kindly contact Mr. Bunhorng Rath, email: rath.bunhorng@gmail.com.

Thank you so much for your participation and best regards,

Mr .Bunhorng Rath

Doctor of Philosophy Student in Logistics and Supply Chain Management

Faculty of Logistics, Burapha University

QRE ID			

Part I: Personal profile

Instruction: please tick (✓) in the box (☐) that is true for you and complete in the space as required:

Q1. Sex	☐	1. Male
	☐	2. Female
Q2. Marital status	☐	1. Single
	☐	2. Married
	☐	3. Widow/ widower
Q3. Age	☐	1. Under 30
	☐	2. 30-39 years old
	☐	3. 40-49 years old
	☐	4. Older than to 50 years
Q4. Educational level	☐	1. Never go to school
	☐	2. Preschool
	☐	3. Primary school
	☐	4. Junior high school
	☐	5. Senior high School
	☐	6. Bachelor
	☐	7. Other (e.g. informal education), specify………………………..
Q5. Experience/ working related to rice farming	☐	1. Less than 5 years
	☐	2. 5-10 years
	☐	3. 11-15 years
	☐	4. 16-20 years
	☐	5. More than 20 years

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Part II: Risk factors that affect performance and risk management strategies

Section 1: Risk factors in rice supply chain

Instruction: please complete and tick (✓) in the box (☐) from 1 to 5 that most closely matches the risk factors that affect to performance of the rice supply chain in Cambodia

5 = “strongly agree” refers to the reality that strongly suitable to the risk factors that affect performance

4 = “agree” refers to the reality that very suitable to the risk factors that affect performance

3 = “neutral” refers to the reality that moderately suitable to the risk factors that affect performance

2 = “disagree” refers to the reality that less suitable to the risk factors that affect performance

1 = “strongly disagree” refers to the reality that very less suitable to the risk factors that affect performance

Definition: Agricultural risk is the possibility of danger that can be caused by the event include losses, uncertainty, and hazard. Risk is a combination in two primary factors (1) the severity of the effects (2) the likelihood in which risk occurs.

Note: Expected loss scenarios = likelihood*severity

Q6. Supply risks

The factors of supply risks		Likert scale (scenarios)				
6.1	Rising costs of raw materials (fertilizer, pesticide, high yield seeds)	1	2	3	4	5
6.2	Rising costs of services (transportation, labor, interest rates or/ and credit)	1	2	3	4	5
6.3	Lack of high yield seeds	1	2	3	4	5
6.4	Lack of labor	1	2	3	4	5
6.5	Lack of equipment and machinery	1	2	3	4	5
Suggestion and comments:						

Q7. Production risks

The factors of production risks		Likert scale (scenarios)				
7.1	Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)	1	2	3	4	5
7.2	Lack of financial capital	1	2	3	4	5
7.3	Misuse of fertilizer or/ and pesticide	1	2	3	4	5
7.4	Lack of agricultural know-how	1	2	3	4	5
Suggestion and comments:						

Q8. Demand risks

The factors of demand risks		Likert scale (scenarios)				
8.1	Low prices of rice products	1	2	3	4	5
8.2	Lack of market information	1	2	3	4	5
8.3	Uncertainty of market demand for quantity	1	2	3	4	5
8.4	Uncertainty of market demand for quality or/ and food safety requirements	1	2	3	4	5
Suggestion and comments:						

Q9. Environmental risks

The factors of environmental risks		Likert scale (scenarios)				
9.1	Natural disasters (flood, drought)	1	2	3	4	5
9.2	Lack of irrigation systems	1	2	3	4	5
9.3	Lack or poor condition of basic infrastructure (roads, electricity)	1	2	3	4	5
9.4	Inadequate support from the government (lack of agricultural know-how training or/ and lack of public extension services)	1	2	3	4	5
9.5	Pandemic risks (Covid-19)	1	2	3	4	5
Suggestion and comments:						

Section 2: Performance indicators in rice supply chain

Instruction: please complete and tick (✓) in the box (☐) from 1 to 5 that most closely matches the performance indicators for the rice supply chain in Cambodia.

5 = "strongly agree" refers to the reality that strongly suitable to the performance indicators

4 = “agree” refers to the reality that very suitable to the performance indicators

3 = “neutral” refers to the reality that moderately suitable to the performance indicators

2 = “disagree” refers to the reality that less suitable to the performance indicators

1 = “strongly disagree” refers to the reality that very less suitable to the performance indicators

What are the effects of risk factors on rice supply chain performance?

Q10. Environmental performance

Environmental performance		**Likert scale of indicators**				
10.1	The consumption rate of energy, which includes electricity and oil, is an important indicator	1	2	3	4	5
10.2	The consumption rate of natural resources such as water and land is an important indicator	1	2	3	4	5
10.3	The environmental pollutants (water, land, and air) is an important indicator	1	2	3	4	5
Suggestion and comments:						

Q11. Social performance

Social performance		**Likert scale of indicators**				
11.1	Food insecurity (the scale of accessibility to foods and eating patterns) is an important indicator	1	2	3	4	5
11.2	Poverty is an important indicator	1	2	3	4	5
11.3	Farmers’ knowledge is an important indicator	1	2	3	4	5
Suggestion and comments:						

Q12. Economic performance

Economic performance		Likert scale of indicators				
12.1	Rice yield of farming household is an important indicator	1	2	3	4	5
12.2	Rice quality (nutritional benefits, softness, aroma, and physical appearance) is an important indicator	1	2	3	4	5
12.3	Return on investment-ROI (net profit divided by the costs of investment) is an important indicator	1	2	3	4	5
Suggestion and comments:						

Section 3: Risk management strategies

Instruction: please complete and tick (✓) in the box (☐) from 1 to 5 that most closely matches the risk management strategies for the rice supply chain in Cambodia.

5 = “strongly agree” refers to the reality that strongly suitable to the risk management strategies

4 = “agree” refers to the reality that very suitable to the risk management strategies

3 = “neutral” refers to the reality that moderately suitable to the risk management strategies

2 = “disagree” refers to the reality that less suitable to the risk management strategies

1 = “strongly disagree” refers to the reality that very less suitable to the risk management strategies

What are risk management strategies in the sustainable rice supply chain management in Cambodia?

Risk management strategies for supply risks		Likert scale				
13.1	Seek alternative suppliers	1	2	3	4	5
13.2	Promote contract farming	1	2	3	4	5
13.3	Provide the incentive to local seed producers and distributors	1	2	3	4	5
13.4	Use the system of "sharing-hand": help each other during the farming period; improve agricultural management practices (e.g., using direct seeding)	1	2	3	4	5
13.5	Offer tax incentives to incentivize the imports of equipment and machinery	1	2	3	4	5
Suggestion and comments:						
14.1	Improve agricultural management practices for biological risks (e.g., better water management, improve seeds); improve the agricultural extension services to commune level	1	2	3	4	5
14.2	Encourage agricultural microfinance	1	2	3	4	5
14.3	Encourage and promote policy on sustainable utilization of farming land (e.g., effective mapping)	1	2	3	4	5
14.4	Develop public policies and enforce for sanitary and phytosanitary standards (e.g., food safety); effective usage of pesticide and fertilizer; avoid risky practices through organic farms	1	2	3	4	5
14.5	Improve productivity by using high-yielding seed and modern agricultural techniques	1	2	3	4	5
14.6	Support and establish Farmer Organization	1	2	3	4	5
14.7	Improve agricultural training	1	2	3	4	5
Suggestion and comments:						

Risk management strategies for supply risks		Likert scale				
15.1	Comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers	1	2	3	4	5
15.2	Improve transparency and market information	1	2	3	4	5
15.3	Promote contract farming with millers/ buyers	1	2	3	4	5
15.4	Improve warehouse management	1	2	3	4	5
15.5	Seek alternative buyers	1	2	3	4	5
Suggestion and comments:						
16.1	Adapt for climate change (e.g., agricultural diversification); purchase insurance; aid or charity from government, international organization, and other donors	1	2	3	4	5
16.2	Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)	1	2	3	4	5
16.3	Construct and maintain roads in the countryside (link rice production areas to markets)	1	2	3	4	5
16.4	Reduce electricity price and promote electric power transmission to rural areas	1	2	3	4	5
16.5	Improve the agricultural extension services to commune level	1	2	3	4	5
16.6	Improve agricultural know-how training	1	2	3	4	5
16.7	Manage Covid-19 affects farmers by investing in the vaccination program, quarantine program, spraying program, strong health systems, advanced R & D	1	2	3	4	5
Suggestion and comments:						

Part III: Recommendations and suggestions

More comments, suggestions, or perception?

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Thank you very much for answering the questions!

มหาวิทยาลัยบูรพา
BURAPHA UNIVERSITY

APPENDIX D

Ethical principles of human research

7

บันทึกข้อความ

ส่วนงาน กองบริหารการวิจัยและนวัตกรรม งานมาตรฐานและจริยธรรมในงานวิจัย โทร. ๒๖๒๐
ที่ อว ๘๑๐๐/๑๒๓๕๘ **วันที่** ๑๑ พฤศจิกายน พ.ศ. ๒๕๖๔
เรื่อง ขอส่งเอกสารรับรองผลการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา

เรียน คณบดีคณะโลจิสติกส์

ตามที่นิสิตระดับบัณฑิตศึกษาในหน่วยงานของท่าน ได้ยื่นเอกสารคำร้องเพื่อขอรับการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา สำหรับโครงการวิจัยระดับบัณฑิตศึกษา และระดับปริญญาตรี ชุดที่ ๔ (กลุ่มมนุษยศาสตร์และสังคมศาสตร์) รหัสโครงการวิจัย G-HU 237/2564 โครงการวิจัย เรื่อง การวิเคราะห์ความเสี่ยงในห่วงโซ่อุปทานข้าวกรณีศึกษาประเทศกัมพูชา (RISK ANALYSIS OF RICE SUPPLY CHAIN IN CAMBODIA) โดยมี MR.BUNHORNG RATH เป็นหัวหน้าโครงการวิจัย นั้น

บัดนี้ คณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา ได้พิจารณาโครงการฉบับนี้ ตามประกาศมหาวิทยาลัย เลขที่ ๑๓๖๖/ ๒๕๖๒ เรื่อง แนวปฏิบัติในการจำแนกโครงการวิจัยเพื่อขอรับการรับรองจากคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา พ.ศ. ๒๕๖๒ ที่ได้ประกาศใช้ เมื่อวันที่ ๕ พฤศจิกายน พ.ศ.๒๕๖๒ แล้วว่า โครงการวิจัยดังกล่าวเป็นโครงการวิจัยที่สามารถให้การรับรอง โดยยกเว้นการลงมติจากที่ประชุม (Exemption Determination) ตามข้อที่ ๕ คือเป็นการวิจัยที่เก็บข้อมูลด้วยวิธีการสำรวจ (Survey) สัมภาษณ์ (Interview) หรือสังเกต (Observe) พฤติกรรมสาธารณะของประชาชนทั่วไป ฯลฯ จึงเห็นสมควรให้ดำเนินการวิจัยได้ พร้อมนี้ ได้แนบเอกสารรับรองผลการพิจารณาจริยธรรมการวิจัยในมนุษย์ (หมายเลขใบรับรองที่ IRB4-291/2564) มายังท่าน เพื่อแจ้งนิสิตระดับบัณฑิตศึกษาที่มีรายชื่อข้างต้น นำไปใช้ในการเก็บข้อมูลจริงจากผู้เข้าร่วมโครงการวิจัยต่อไป โดยห้ามนิสิตฯ เบี่ยงเบนรายละเอียดต่างๆ ของโครงการวิจัยที่ยื่นมาขอรับการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา และเมื่อนิสิตฯ ดำเนินการวิจัยเสร็จเรียบร้อยแล้ว ขอให้แจ้งปิดโครงการวิจัยมายังคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา ด้วย

จึงเรียนมาเพื่อโปรดแจ้งให้นิสิตฯ ทราบ จะขอบคุณยิ่ง

(ดร.พิมลพรรณ เลิศล้ำ)
ประธานคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์มหาวิทยาลัยบูรพา
สำหรับโครงการวิจัยระดับบัณฑิตศึกษา และระดับปริญญาตรี
ชุดที่ ๔ (กลุ่มมนุษยศาสตร์และสังคมศาสตร์)

หมายเหตุ : ผู้วิจัยสามารถดาวน์โหลดเอกสารชี้แจงผู้เข้าร่วมโครงการวิจัย เอกสารแสดงความยินยอมของผู้เข้าร่วมโครงการวิจัย และเอกสารเครื่องมือที่ใช้ในการวิจัยต่างๆ ซึ่งผ่านการประทับตรารับรองเรียบร้อยแล้ว ได้ที่ระบบการขอรับพิจารณาจริยธรรมการวิจัยแบบออนไลน์ (BUU Ethics Submission Online) เพื่อนำไปใช้ในการเก็บข้อมูลจริงจากผู้เข้าร่วมโครงการวิจัยต่อไป

บันทึกข้อความ

ส่วนงาน กองบริหารการวิจัยและนวัตกรรม งานมาตรฐานและจริยธรรมในการวิจัย โทร. ๒๖๒๐
ที่ อว ๘๑๐๐/- **วันที่** ๑๐ เดือน พฤศจิกายน พ.ศ. ๒๕๖๔
เรื่อง ขอส่งสำเนาเอกสารรับรองผลการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา

เรียน MR.BUNHORNG RATH

ตามที่ท่าน ได้ยื่นเอกสารคำร้องเพื่อขอรับการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา รหัสโครงการวิจัย G-HU237/2564(E1) โครงการวิจัย เรื่อง
การวิเคราะห์ความเสี่ยงในห่วงโซ่อุปทานข้าวกรณีศึกษาประเทศกัมพูชา นั้น

บัดนี้ โครงการวิจัยดังกล่าว ได้ผ่านการพิจารณาจากคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา สำหรับโครงการวิจัยระดับบัณฑิตศึกษาและระดับปริญญาตรี ชุดที่ 4
(กลุ่มมนุษยศาสตร์และสังคมศาสตร์) เป็นที่เรียบร้อยแล้ว กองบริหารการวิจัยและนวัตกรรม ในฐานะผู้ประสานงาน จึงขอส่งสำเนาเอกสารรับรองผลการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา จำนวน ๑ ฉบับ เอกสารชี้แจงผู้เข้าร่วมโครงการวิจัย เอกสารแสดงความยินยอมของผู้เข้าร่วมโครงการวิจัย และเอกสารเครื่องมือที่ใช้ในการวิจัย โดยประทับตรารับรองเรียบร้อยแล้ว มายังท่าน เพื่อนำไปใช้ในการเก็บข้อมูลจริงจากผู้เข้าร่วมโครงการวิจัยต่อไป

จึงเรียนมาเพื่อโปรดทราบ

นางสาวพิมลพรรณ เลิศล้ำ
(นางสาวพิมลพรรณ เลิศล้ำ)
ประธานคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา
สำหรับโครงการวิจัยระดับบัณฑิตศึกษาและระดับปริญญาตรี
ชุดที่ 4 (กลุ่มมนุษยศาสตร์และสังคมศาสตร์)

Certificate Number IRB4-291/2564

Certificate of Human Research Approval

Burapha University

BUU Ethics Committee for Human Research has considered the following research protocol

Protocol Code : G-HU 237/2564

Protocol Title : RISK ANALYSIS OF RICE SUPPLY CHAIN IN CAMBODIA

Principal Investigator : MR.BUNHORNG RATH

Affiliation : Graduate Program of Faculty of Logistics

BUU Ethics Committee for Human Research has considered the following research protocol according to the ethical principles of human research in which the researchers respect human's right and honor, do not violate right and safety, and do no harms to the research participants.

Therefore, the research protocol is approved (See attached)

1. Form of Human Research Protocol Submission	Version 1 : 5 November 2021
2. Research Protocol	Version 1 : 5 November 2021
3. Participant Information Sheet	Version 1 : 5 November 2021
4. Informed Consent Form	Version 1 : 5 November 2021
5. Research Instruments	Version 1 : 5 November 2021
6. Others (if any)	Version - : -

Approval Date : 5 November 2021

Valid Date : 5 November 2022

Sign

(Pimonpan Lertlam)

Chair of The Burapha University Institutional Review Board

Panel 4 (Humanities and Social Sciences)

BURAPHA UNIVERSITY

สำเนา

ที่ IRB4-291/2564

เอกสารรับรองผลการพิจารณาจริยธรรมการวิจัยในมนุษย์

มหาวิทยาลัยบูรพา

คณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา ได้พิจารณาโครงการวิจัย

รหัสโครงการวิจัย : G-HU237/2564

โครงการวิจัยเรื่อง : การวิเคราะห์ความเสี่ยงในห่วงโซ่อุปทานข้าวกรณีศึกษาประเทศกัมพูชา

หัวหน้าโครงการวิจัย : MR.BUNHORNG RATH

หน่วยงานที่สังกัด : คณะโลจิสติกส์

BUU Ethics Committee for Human Research has considered the following research protocol according to the ethical principles of human research in which the researchers respect human's right and honor, do not violate right and safety, and do no harms to the research participants.

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5. Research Instruments Version 1 : 5 November 2021
6. Others (if any) Version - : -

วันที่รับรอง : วันที่ 5 เดือน พฤศจิกายน พ.ศ. 2564

วันที่หมดอายุ : วันที่ 5 เดือน พฤศจิกายน พ.ศ. 2565

ลงนาม *นางสาวพิมลพรรณ เลิศล้ำ*

(นางสาวพิมลพรรณ เลิศล้ำ)

ประธานคณะกรรมการพิจารณาจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยบูรพา

ชุดที่ 4 (กลุ่มมนุษยศาสตร์และสังคมศาสตร์)

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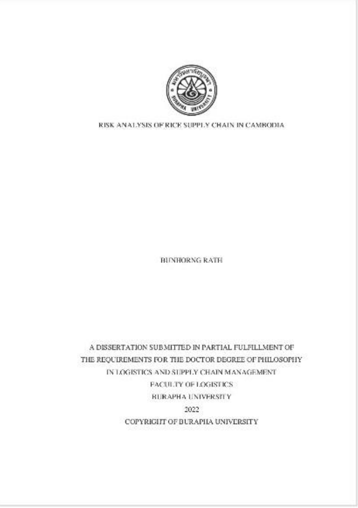
RISK ANALYSIS OF RICE SUPPLY CHAIN IN CAMBODIA

BUNHORNG RATH

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DOCTOR DEGREE OF PHILOSOPHY
IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT
FACULTY OF LOGISTICS
BURAPHA UNIVERSITY
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CHAPTER 2 LITERATURE REVIEW (Rath, 2022)

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CHAPTER 5 SUMMARY OF RESEARCH FINDING...APPENDIX, & OTHER (Rath, 2022)

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APPENDIX E

Results of data analysis

1. Abbreviations and symbols in this data analysis

1. $\bar{x}$ = Sample mean
2. SD = Sample standard deviation
3. s. e. = Standard error
4. CV = coefficient of variation
5. SK = Skewness
6. KU = Kurtosis
7. X^2 = Chi-square
8. df = Degrees of freedom
9. X^2/ df = Relative chi-square
10. p = $p-$value
11. t = $t-$value
12. RMSEA = Root mean square error of approximation
13. RMR = Root mean square residual
14. GFI = Goodness-of-fit index
15. NFI = Normed fit index
16. TLI = Tucker–Lewis index
17. C.R. = Critical ratio
18. R^2 = Coefficient of determination
19. Y = Dependent variable
20. X = Independent variable
21. TE = Totals Effects
22. DE = Direct Effects
23. IE = Indirect Effects
24. H = Hypothesis
25. H_0 = Null hypothesis
26. H_1 = Alternative hypothesis
27. H1 = Hypothesis 1: Rice supply chain performance is significantly affected by the rice supply chain risks

28.	H2	=	Hypothesis 2: There is a relationship between environmental performance and social performance
29.	H3	=	Hypothesis 3: There is a relationship between social performance and economic performance
30.	H4	=	Hypothesis 4: There is a relationship between environmental performance and economic performance
31.	R11	=	Rising costs of raw materials (fertilizer, pesticide, high yield seeds, fuel)
32.	R12	=	Rising costs of services (transportation, labor, interest rates or/ and credit, other agricultural services)
33.	R13	=	Lack of high yield seeds
34.	R14	=	Lack of labor
35.	R15	=	Lack of equipment and machinery
36.	R21	=	Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)
37.	R22	=	Lack of financial capital
38.	R23	=	Misuse of fertilizer or/ and pesticide
39.	R24	=	Lack of agricultural know-how
40.	R31	=	Low prices of rice products
41.	R32	=	Lack of market information
42.	R33	=	Uncertainty of market demand for quantity
43.	R34	=	Uncertainty of market demand for quality or/ and food safety requirements
44.	R41	=	Natural disasters (flood, drought)
45.	R42	=	Lack of irrigation systems
46.	R43	=	Lack or poor condition of basic infrastructure (roads, electricity)

47. R44 = Inadequate support from the government (lack of agricultural know-how training, and/ or lack of public extension services)
48. R45 = Pandemic risks (Covid-19)
49. P11 = The consumption rate of energy, which includes electricity and oil
50. P12 = The consumption rate of natural resources such as water and land
51. P13 = The environmental pollutants (water, land, and air)
52. P21 = Food insecurity (the scale of accessibility to foods and eating patterns)
53. P22 = Poverty
54. P23 = Farmers' knowledge
55. P31 = Rice yield of farming household
56. P32 = Rice quality (nutritional benefits, softness, aroma, and physical appearance)
57. P33 = Return on investment-ROI (net profit divided by the costs of investment)
58. M1 = Seek alternative suppliers (management strategy 1)
59. M2 = Promote contract farming
60. M3 = Provide the incentive to local seed producers and distributors
61. M4 = Use the system of "sharing-hand": help each other during the farming period; improve agricultural management practices (e.g., using direct seeding)
62. M5 = Offer tax incentives to incentivize the imports of equipment and machinery

63.	M6	=	Improve agricultural management practices for biological risks (e.g., better water management, improve seeds); improve the agricultural extension services to commune level
64.	M7	=	Encourage agricultural microfinance
65.	M8	=	Encourage and promote policy on sustainable utilization of farming land (e.g., effective mapping)
66.	M9	=	Develop public policies and enforce regarding sanitary and phytosanitary standards (e.g., food safety); use pesticide and fertilizer effectively; avoid risky practices through organic farms
67.	M10	=	Improve productivity by using high-yielding seed and modern agricultural techniques
68.	M11	=	Support and establish Farmer Organization
69.	M12	=	Improve agricultural training
70.	M13	=	Conduct comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers
71.	M14	=	Improve transparency and market information
72.	M15	=	Promote contract farming with millers/ buyers
73.	M16	=	Improve warehouse management
74.	M17	=	Seek alternative buyers
75.	M18	=	Adapt for climate change (e.g., agricultural diversification); purchase insurance; aid or charity from government, international organization, and other donors
76.	M19	=	Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)

77.	M20	=	Construct and maintain roads in the countryside (link rice production areas to markets)
78.	M21	=	Reduce electricity price and promote electric power transmission to rural areas
79.	M22	=	Improve the agricultural extension services to commune level
80.	M23	=	Improve agricultural know-how training
81.	M24	=	Manage Covid-19 affects farmers by investing in the vaccination program, quarantine program, robust health systems, advanced R & D
82.	RM	=	Risk mitigation
83.	RA	=	Risk avoidance
84.	RT	=	Risk transfer
85.	RC	=	Risk coping
86.	MAFF	=	Ministry of Agriculture, Forestry and Fisheries
87.	MOC	=	Ministry of Commerce
88.	MEF	=	Ministry of Economy and Finance
89.	MFAIC	=	Ministry of Foreign Affairs and International Cooperation
90.	MOH	=	Ministry of Health of Cambodia
91.	MISTI	=	Ministry of Industry, Science, Technology and Innovation
92.	MLMUPC	=	Ministry of Land Management, Urban Planning and Construction
93.	MME	=	Ministry of Mines and Energy
94.	MOP	=	Ministry of Planning
95.	MPWT	=	Ministry of Public Works and Transport
96.	MRD	=	Ministry of Rural Development
97.	MOWRAM	=	Ministry of Water Resources and Meteorology
98.	NBC	=	National Bank of Cambodia
99.	NIS	=	National Institute of Statistics of Cambodia
100.	EAC	=	Electricity Authority of Cambodia

Examination of the construct validity and consistency of this questionnaire (Risk analysis of rice supply chain in Cambodia)

Introduction:

1. This study is a partial fulfillment of the requirements for a Ph.D. in Logistics and Supply Chain Management, Faculty of Logistics, Burapha University.

2. The primary objective of this research attempts to analyze the risks in the rice supply chain. This study focuses on three specific purposes, which are 1) to identify the agricultural risk factors in the rice supply chain, 2) to investigate risk factors that affect rice supply chain performance in Cambodia, and 3) to propose risk management strategies in the sustainable rice supply chain management in Cambodia. The researcher would like to request you to examine the validity of this questionnaire to achieve maximum benefits.

3. The result of this study will be useful to develop the rice supply chain in Cambodia.

4. The examination of the construct validity and consistency of this questionnaire consists of three parts:

Part 1: The basic profile of the expert

Part 2: The variables in this study

Part 3: Other comments and suggestion to improve this questionnaire

5. The data, which got from this questionnaire, is employed to analyze the overall aspects of risk in the rice supply chain for academic purposes only; there is no way to impact neither the respondents nor their position. Your contribution to this study is voluntary and anonymous. We will not reveal your personal information that could lead to the identifying of any individual or your organization to any other external parties or research project without your authorization.

Thank you so much for your participation and best regards,

Mr. Bunhorng Rath
Doctor of Philosophy Student in Logistics and Supply Chain Management
Faculty of Logistics, Burapha University

PART I: The basic profile of the expert

Instruction: please complete in the space that is true for you as required:

Experts: Name/ Position/ Affiliated Institute/ University/ Address

1. Dr. Sarawut Jansuwan, Assistant Professor, Department of Logistics Management, National Institute of Development Administration (NIDA), Thailand

2. Dr. Juthathip Suraraksa, Assistant Professor, Faculty of Logistics, Burapha University, Thailand

3. Dr. Pao Srean, Dean, Faculty of Agriculture and Food Processing, National University of Battambang, Cambodia

4. Dr. Sokvibol Kea, Lecturer, Faculty of Sociology and Community Development, National University of Battambang, Cambodia

5. Dr. Lyna Prak, Lecturer, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Thailand

PART 2: The variables in this study

Introduction: please consider the below measures to meet the objective and definition or not.

Instruction: please tick (✓) in the box (☐) that is true for you and complete in the space as required:

- Score=+1 indicates that you think this is suitable
- Score=0 indicates that you are not sure
- Score=-1 indicates that you think this is unsuitable

Result of the examination of the construct validity and consistency:

Item		Experts' perceptions					IOC	Comments
Section 1: Risks								
1.1 The factors of supply risks								
1	Rising costs of raw materials (fertilizer, pesticide, high yield seeds)	+1	+1	+1	+1	+1	1.0	
2	Rising costs of services (transportation, labor, interest rates or/ and credit)	+1	+1	+1	+1	+1	1.0	
3	Lack of high yield seeds	+1	+1	+1	0	+1	0.8	
4	Lack of labor	+1	0	+1	0	+1	0.6	
5	Lack of equipment and machinery	+1	0	+1	+1	+1	0.8	
1.2 The factors of production risks								
6	Biological risks such as weeds (wild plants); pests (insects, rats, snails, or birds); crop diseases (bacteria, viruses, or fungi)	+1	+1	+1	+1	+1	1.0	
7	Lack of financial capital	+1	0	+1	+1	+1	0.8	
8	Misuse of fertilizer or/ and pesticide	0	+1	+1	+1	+1	0.8	
9	Lack of agricultural know-how	0	+1	+1	+1	+1	0.8	
1.3 The factors of demand risks								
10	Low prices of rice products	+1	+1	+1	+1	+1	1.0	
11	Lack of market information	+1	+1	+1	+1	+1	1.0	

Item		Experts' perceptions					IOC	Comments
12	Uncertainty of market demand for quantity	+1	+1	+1	+1	+1	1.0	
13	Uncertainty of market demand for quality or/ and food safety requirements	+1	+1	+1	+1	+1	1.0	
1.4 The factors of environmental risks								
14	Natural disasters (flood, drought)	+1	+1	+1	+1	+1	1.0	
15	Lack of irrigation systems	+1	+1	+1	+1	+1	1.0	
16	Lack or poor condition of basic infrastructure (roads, electricity)	+1	+1	+1	+1	+1	1.0	
17	Inadequate support from the government (lack of agricultural know-how training or/ and lack of public extension services)	+1	0	+1	+1	+1	0.8	
18	Pandemic risks (Covid-19)	+1	+1	+1	+1	0	0.8	
Section 2: Performance								
2.1 Environmental performance								
1	The consumption rate of energy which includes electricity and oil	0	+1	+1	+1	+1	0.8	
2	The consumption rate of natural resources such as water and land	0	+1	+1	+1	+1	0.8	
3	The environmental pollutants (water, land, and air)	0	+1	+1	+1	+1	0.8	

Item		Experts' perceptions					IOC	Comments
2.2 Social performance								
4	Food insecurity (the scale of accessibility to foods and eating patterns)	-1	+1	+1	+1	+1	0.6	
5	Poverty	-1	+1	+1	+1	+1	0.6	
6	Farmers' knowledge	+1	+1	0	+1	+1	0.8	
2.3 Economic performance								
7	Rice yield of farming household	+1	+1	+1	+1	+1	1.0	
8	Rice quality (nutritional benefits, softness, aroma, and physical appearance)	+1	+1	+1	+1	+1	1.0	
9	Return on investment-ROI (net profit divided by the costs of investment)	+1	+1	-1	+1	+1	0.6	
Section 3: Risk management strategies								
3.1 Risk management strategies for supply risks								
1	Seek alternative suppliers	+1	+1	+1	+1	+1	1.0	
2	Promote contract farming	+1	+1	+1	+1	+1	1.0	
3	Provide the incentive to local seed producers and distributors	0	+1	+1	+1	+1	0.8	
4	Use the system of "sharing-hand": help each other during the farming period; improve agricultural management practices (e.g., using direct seeding)	0	0	+1	+1	+1	0.6	

Item		Experts' perceptions					IOC	Comments
5	Offer tax incentives to incentivize the imports of equipment and machinery	+1	0	+1	+1	+1	0.8	
3.2 Risk management strategies for production risks								
6	Improve agricultural management practices for biological risks (e.g., better water management, improve seeds); improve the agricultural extension services to commune level	0	+1	+1	+1	+1	0.8	
7	Encourage agricultural microfinance	+1	0	+1	+1	+1	0.8	
8	Encourage and promote policy on sustainable utilization of farming land (e.g., effective mapping)	+1	0	+1	+1	+1	0.8	
9	Develop public policies and enforce for sanitary and phytosanitary standards (e.g., food safety); effective usage of pesticide and fertilizer; avoid risky practices through organic farms	0	+1	+1	+1	+1	0.8	
10	Improve productivity by using high-yielding seed and modern agricultural techniques	0	+1	+1	+1	+1	0.8	

Item		Experts' perceptions					IOC	Comments
11	Support and establish Farmer Organization	0	+1	+1	+1	+1	0.8	
12	Improve agricultural training	0	+1	+1	+1	+1	0.8	
3.3 Risk management strategies for demand risks								
13	Comprehensive research or study on national and international markets, which are potential for rice, to explore the opportunities; broadcast and spread the research results to a wide range of rice producers	-1	+1	+1	+1	+1	0.6	
14	Improve transparency and market information	+1	+1	+1	+1	+1	1.0	
15	Promote contract farming with millers/ buyers	+1	+1	+1	+1	+1	1.0	
16	Improve warehouse management	+1	+1	+1	+1	+1	1.0	
17	Seek alternative buyers	+1	+1	+1	+1	+1	1.0	
3.4 Risk management strategies for environmental risks								
18	Adapt for climate change (e.g., agricultural diversification); purchase insurance; aid or charity from government, international organization, and other donors	-1	+1	+1	+1	+1	0.6	

Item		Experts' perceptions					IOC	Comments
19	Develop irrigation (use existing water resources effectively; repair and upgrade existing irrigation; invest in new irrigation)	0	+1	+1	+1	+1	0.8	
20	Construct and maintain roads in the countryside (link rice production areas to markets)	+1	+1	+1	+1	+1	1.0	
21	Reduce electricity price and promote electric power transmission to rural areas	+1	+1	+1	+1	+1	1.0	
22	Improve the agricultural extension services to commune level	+1	+1	+1	+1	+1	1.0	
23	Improve agricultural know-how training	+1	+1	+1	+1	+1	1.0	
24	Manage Covid-19 affects farmers by investing in the vaccination program, quarantine program, spraying program, strong health systems, advanced R & D	-1	+1	+1	+1	+1	0.6	

*IOC = 0.9

PART III: Recommendations and suggestions

……………………………………...……………………………………………………………………

……………………………………...……………………………………………………………………

Thank you very much for your participation!

BURAPHA UNIVERSITY

3. Results of data analysis from the second pilot test

Second pilot test (n = 30): to evaluate the questions in the questionnaire by alpha value from 0 (low reliability) to 1 (high reliability). Cronbach's alpha reliability (∝) was considered as follows:

$\alpha \geq 0.9$ = Excellent

$0.9 > \alpha \geq 0.8$ = Good

$0.8 > \alpha \geq 0.7$ = Acceptable

$0.7 > \alpha \geq 0.6$ = Uncertain

$0.6 > \alpha \geq 0.5$ = Poor

$\alpha > 0.5$ = Rejected

Table E1 Personal details of informants from the second pilot test

		Total (second pilot test, n=30)	
		Frequency	**Percent**
Sex	Male	22	73.3
	Female	8	26.7
Marital status	Single	21	70.0
	Married	9	30.0
Age	Under 30	21	70.0
	30-39 years old	8	26.7
	Older than to 50 years	1	3.3
Educational level	Junior high school	1	3.3
	Senior high school	8	26.7
	Bachelor	20	66.7
	Master	1	3.3
Rice farming experience	Less than 5 years	18	60.0
	5-10 years	9	30.0
	16-20 years	2	6.7
	More than 20 years	1	3.3

Table E1 Overall reliability statistics

Cronbach’s Alpha	Cronbach's alpha based on standardized items	N of Items	Result
.933	.935	51	Excellent

Table E3 Cronbach's Alpha and result of each dimension

	Cronbach’s Alpha	Result
Factors of supply risks	.761	Acceptable
Factors of production risks	.869	Good
Factors of demand risks	.811	Good
Factors of environmental risks	.815	Good
Environmental performance	.668	Uncertain
Social performance	.809	Good
Economic performance	.725	Acceptable
Risk management strategies	.920	Excellent

Table E4 Item statistics from the second pilot test

No	VAR.	Mean	Std. Deviation	N	Question order
Supply risks					
1.	X11	4.033	1.1592	30	1
2.	X12	3.900	1.0289	30	2
3.	X13	3.900	1.0619	30	3
4.	X14	3.600	1.1626	30	4
5.	X15	3.667	1.0933	30	5
Production risks					
6.	X21	4.100	1.0619	30	1
7.	X22	4.033	1.0981	30	2

No	VAR.	Mean	Std. Deviation	N	Question order
8.	X23	3.967	1.0662	30	3
9.	X24	3.800	1.1265	30	4
Demand risks					
10.	X31	4.567	1.0400	30	1
11.	X32	4.367	.8503	30	2
12.	X33	4.100	1.0619	30	3
13.	X34	3.967	.9643	30	4
Environmental risks					
14.	X41	3.833	1.0532	30	1
15.	X42	4.067	1.1427	30	2
16.	X43	3.733	1.1121	30	3
17.	X44	3.967	1.0981	30	4
18.	X45	3.867	1.1958	30	5
Environmental performance					
19.	Y11	3.667	.8442	30	1
20.	Y12	3.667	.9223	30	2
21.	Y13	4.000	.9469	30	3
Social performance					
22.	Y21	3.533	.9732	30	1
23.	Y22	4.100	.9595	30	2
24.	Y23	3.967	.8503	30	3
Economic performance					
25.	Y31	3.933	.7397	30	1
26.	Y32	4.000	.7878	30	2
27.	Y33	4.000	.9469	30	3
Risk management strategies for supply risks					
28.	M1	4.400	.7240	30	1
29.	M2	4.267	.8277	30	2
30.	M3	4.533	.6288	30	3

No	VAR.	Mean	Std. Deviation	N	Question order
31.	M4	3.900	.8847	30	4
32.	M5	4.267	.9803	30	5
Risk management strategies for production risks					
33.	M6	4.400	.5632	30	1
34.	M7	4.467	.5074	30	2
35.	M8	4.533	.8193	30	3
36.	M9	4.333	.6065	30	4
37.	M10	4.500	.6297	30	5
38.	M11	4.467	.5713	30	6
39.	M12	4.633	.4901	30	7
Risk management strategies for demand risks					
40.	M13	4.267	.7397	30	1
41.	M14	4.567	.6261	30	2
42.	M15	4.500	.6823	30	3
43.	M16	4.300	.6513	30	4
44.	M17	4.633	.5561	30	5
Risk management strategies for environmental risks					
45.	M18	4.033	.7184	30	1
46.	M19	4.533	.6288	30	2
47.	M20	4.533	.5074	30	3
48.	M21	4.600	.4983	30	4
49.	M22	4.400	.7701	30	5
50.	M23	4.567	.5683	30	6
51.	M24	4.500	.5724	30	7

4. The result of structural equation modeling from Amos program

Analysis Summary

Date and Time

Date: Thursday, January 20, 2022

Time: 10:20:31 PM

Title

Phd_sem010_: Thursday, January 20, 2022 10:20 PM

Groups

Group number 1 (Group number 1)

Notes for Group (Group number 1)

The model is recursive.

Sample size = 200

Variable Summary (Group number 1)

Your model contains the following variables (Group number 1)

Observed, endogenous variables

X11

X12

X13

X14

X15

X24

X23

X22

X21

X34

X33

X32

X31

X45

X44

X43

X42

X41

Y11

Y12

Y13

Y21

Y22

Y23

Y31

Y32

Y33

Unobserved, endogenous variables

SR

PR

DR

ER

ENVI

SOC

ECON

PERF

Unobserved, exogenous variables

d1

d2

d3

d4

d5

d9

d8

d7

d6

d13

d12

d11

d10

d18

d17

d16

d15

d14

e1

e2

e3

e4

e5

e6

e7

e8

e9

RISK

F1

F2

F3

Variable counts (Group number 1)

Number of variables in your model: 66

Number of observed variables: 27

Number of unobserved variables: 39

Number of exogenous variables: 31

Number of endogenous variables: 35

Assessment of normality (Group number 1)

Variable	Min	Max	M	SD	Skew	Kurtosis
X11	1.0	5.0	4.1	1.1	-1.4	1.6
X12	1.0	5.0	3.9	1	-1.0	0.8
X13	1.0	5.0	3.8	0.9	-0.6	0.2
X14	1.0	5.0	3.6	1	-0.6	-
X15	1.0	5.0	3.8	1	-0.6	-0.1
X21	1.0	5.0	4	0.9	-0.9	0.8
X22	1.0	5.0	4	0.9	-0.7	0.1
X23	1.0	5.0	3.9	0.9	-1.1	1.5
X24	1.0	5.0	4.1	0.8	-0.8	1.0
X31	1.0	5.0	4.4	1	-1.9	3.4
X32	1.0	5.0	4.3	0.9	-1.5	2.7
X33	1.0	5.0	4.1	0.9	-1.2	1.7
X34	1.0	5.0	4.1	0.8	-0.8	0.5
X41	1.0	5.0	4.1	0.9	-0.7	0.1
X42	1.0	5.0	4.2	0.8	-1.1	1.5
X43	1.0	5.0	3.9	0.9	-0.6	0.2
X44	1.0	5.0	4	0.9	-0.8	0.3
X45	1.0	5.0	4.1	1	-1.1	0.9
Y11	1.0	5.0	3.9	0.8	-0.8	1.2
Y12	1.0	5.0	3.8	0.7	-0.8	1.9
Y13	1.0	5.0	4	0.9	-0.9	0.9
Y21	1.0	5.0	3.7	0.8	-0.5	0.3
Y22	1.0	5.0	4.1	0.9	-0.9	0.8
Y23	1.0	5.0	4	0.8	-0.7	0.8
Y31	1.0	5.0	3.9	0.9	-0.6	0.4
Y32	1.0	5.0	3.8	0.8	-0.6	0.7
Y33	1.0	5.0	4	0.9	-0.7	0.5

Sample Moments (Group number 1); Sample Correlations (Group number 1)

Y33 Y32 Y31 Y23 Y22 Y21 Y13 Y12 Y11 X41 X42 X43 X44 X45 X31 X32 X33 X34 X21 X22 X23 X24 X15 X14 X13 X12 X11
Y33 1.000
Y32 .332 1.000
Y31 .477 .454 1.000
Y23 .349 .419 .620 1.000
Y22 .267 .269 .480 .504 1.000
Y21 .271 .278 .382 .351 .461 1.000
Y13 .400 .286 .403 .261 .396 .391 1.000
Y12 .340 .329 .396 .392 .299 .308 .407 1.000
Y11 .335 .376 .356 .318 .304 .310 .403 .544 1.000
X41 .095 .169 .273 .222 .150 .200 .257 .329 .196 1.000
X42 .137 .177 .311 .294 .256 .290 .372 .387 .380 .442 1.000
X43 .207 .222 .292 .294 .279 .324 .315 .353 .466 .242 .549 1.000
X44 .341 .258 .295 .306 .227 .256 .178 .313 .242 .300 .478 .546 1.000
X45 .158 .216 .163 .155 .304 .137 .337 .249 .533 .226 .312 .379 .335 1.000
X31 .323 .020 .278 .215 .332 .264 .466 .364 .354 .362 .437 .378 .390 .289 1.000
X32 .251 .154 .243 .254 .365 .239 .410 .342 .306 .343 .414 .354 .416 .332 .618 1.000
X33 .205 .079 .268 .238 .357 .225 .248 .368 .280 .335 .330 .323 .470 .329 .518 .599 1.000
X34 .287 .122 .277 .195 .284 .239 .390 .336 .229 .345 .369 .322 .415 .304 .479 .635 .615 1.000
X21 .174 .114 .312 .253 .238 .274 .396 .261 .248 .370 .352 .302 .256 .226 .326 .302 .315 .328 1.000
X22 .265 .094 .235 .302 .268 .266 .272 .334 .235 .163 .299 .260 .297 .255 .184 .206 .250 .150 .291 1.000
X23 .093 .141 .245 .226 .295 .173 .282 .321 .138 .311 .296 .241 .434 .281 .298 .330 .360 .294 .284 .329 1.000
X24 .188 .221 .237 .271 .245 .110 .370 .334 .250 .291 .366 .213 .283 .306 .283 .374 .302 .400 .333 .212 .469 1.000
X15 .059 .252 .232 .270 .203 .294 .284 .296 .306 .154 .312 .293 .235 .199 .211 .249 .207 .248 .293 .403 .296 .219 1.000
X14 .024 .184 .220 .160 .141 .195 .205 .295 .237 .178 .113 .133 .132 .119 .163 .125 .211 .201 .184 .194 .306 .119 .489 1.000
X13 .062 .162 .170 .234 .216 .229 .227 .156 .135 .251 .234 .215 .237 .222 .284 .289 .225 .360 .251 .298 .232 .302 .440 .372 1.000
X12 .300 .134 .230 .161 .157 .115 .220 .212 .197 .183 .039 .278 .206 .215 .194 .100 .156 .225 .197 .266 .229 .091 .268 .359 .268 1.000
X11 .272 .071 .121 .066 .035 .089 .243 .115 .094 .219 .112 .166 .200 .149 .289 .209 .165 .261 .229 .219 .136 .116 .182 .224 .309 .621 1.000

Notes for model (Default model)

Computation of degrees of freedom (Default model)

Number of distinct sample moments: 378

Number of distinct parameters to be estimated: 173

Degrees of freedom (378-173): 205

Result (Default model)

Minimum was achieved

Chi-square = 116.139

Degrees of freedom = 205

Probability level = 1.000

Group number 1 (Group number 1-Default model)

Estimates (Group number 1-Default model)

Scalar Estimates (Group number 1-Default model)

Maximum likelihood estimates

			C.R.	P
PERF	<---	RISK	3.48	***
ENVI	<---	PERF		
SOC	<---	PERF	5.614	***
ECON	<---	PERF	6.02	***
SR	<---	RISK		
PR	<---	RISK	3.538	***
DR	<---	RISK	3.691	***
ER	<---	RISK	3.483	***
X11	<---	SR		
X12	<---	SR	4.497	***
X13	<---	SR	3.587	***
X14	<---	SR	3.115	**
X15	<---	SR	3.407	***
X24	<---	PR		
X23	<---	PR	6.724	***

			C.R.	**P**
X22	<---	PR	5.676	***
X21	<---	PR	6.301	***
X34	<---	DR		
X33	<---	DR	8.22	***
X32	<---	DR	9.006	***
X31	<---	DR	7.674	***
X45	<---	ER		
X44	<---	ER	5.847	***
X43	<---	ER	6.364	***
X42	<---	ER	6.468	***
X41	<---	ER	5.644	***
Y11	<---	ENVI		
Y12	<---	ENVI	8.118	***
Y13	<---	ENVI	7.09	***
Y21	<---	SOC		
Y22	<---	SOC	7.322	***
Y23	<---	SOC	7.145	***
Y31	<---	ECON		
Y32	<---	ECON	7.196	***
Y33	<---	ECON	7.585	***

Standardized regression weights: (Group number 1 - default model)

Estimate			
PERF	<---	RISK	1
ENVI	<---	PERF	0.901
SOC	<---	PERF	0.64
ECON	<---	PERF	0.576
SR	<---	RISK	1
PR	<---	RISK	1
DR	<---	RISK	1
ER	<---	RISK	1
X11	<---	SR	0.282
X12	<---	SR	0.377
X13	<---	SR	0.423
X14	<---	SR	0.307
X15	<---	SR	0.476
X24	<---	PR	0.58
X23	<---	PR	0.498
X22	<---	PR	0.526
X21	<---	PR	0.559
X34	<---	DR	0.606
X33	<---	DR	0.561
X32	<---	DR	0.635
X31	<---	DR	0.669
X45	<---	ER	0.527
X44	<---	ER	0.512
X43	<---	ER	0.56
X42	<---	ER	0.631
X41	<---	ER	0.519
Y11	<---	ENVI	0.556
Y12	<---	ENVI	0.642
Y13	<---	ENVI	0.68

Estimate			
Y21	<---	SOC	0.638
Y22	<---	SOC	0.73
Y23	<---	SOC	0.71
Y31	<---	ECON	0.788
Y32	<---	ECON	0.567
Y33	<---	ECON	0.606

Squared multiple correlations: (Group number 1-default model)

Estimate	
ECON	0.332
SOC	0.41
ENVI	0.812
Y33	0.367
Y32	0.322
Y31	0.621
Y23	0.504
Y22	0.533
Y21	0.407
Y13	0.462
Y12	0.412
Y11	0.309

Matrices (Group number 1-Default model)

Standardized Total Effects (Group number 1-Default model)

	RISK	PERF	ECON	SOC	ENVI	ER	DR	PR	SR
PERF	1	0	0	0	0	0	0	0	0
ECON	0.576	0.576	0	0	0	0	0	0	0
SOC	0.64	0.64	0	0	0	0	0	0	0
ENVI	0.901	0.901	0	0	0	0	0	0	0
ER	1	0	0	0	0	0	0	0	0
DR	1	0	0	0	0	0	0	0	0
PR	1	0	0	0	0	0	0	0	0
SR	1	0	0	0	0	0	0	0	0
Y33	0.349	0.349	0.606	0	0	0	0	0	0
Y32	0.327	0.327	0.567	0	0	0	0	0	0
Y31	0.454	0.454	0.788	0	0	0	0	0	0
Y23	0.454	0.454	0	0.71	0	0	0	0	0
Y22	0.467	0.467	0	0.73	0	0	0	0	0
Y21	0.409	0.409	0	0.638	0	0	0	0	0
Y13	0.612	0.612	0	0	0.68	0	0	0	0
Y12	0.578	0.578	0	0	0.642	0	0	0	0
Y11	0.501	0.501	0	0	0.556	0	0	0	0
X41	0.519	0	0	0	0	0.519	0	0	0
X42	0.631	0	0	0	0	0.631	0	0	0
X43	0.56	0	0	0	0	0.56	0	0	0
X44	0.512	0	0	0	0	0.512	0	0	0
X45	0.527	0	0	0	0	0.527	0	0	0
X31	0.669	0	0	0	0	0	0.669	0	0
X32	0.635	0	0	0	0	0	0.635	0	0
X33	0.561	0	0	0	0	0	0.561	0	0
X34	0.606	0	0	0	0	0	0.606	0	0
X21	0.559	0	0	0	0	0	0	0.559	0

	RISK	PERF	ECON	SOC	ENVI	ER	DR	PR	SR
X22	0.526	0	0	0	0	0	0	0.526	0
X23	0.498	0	0	0	0	0	0	0.498	0
X24	0.58	0	0	0	0	0	0	0.58	0
X15	0.476	0	0	0	0	0	0	0	0.476
X14	0.307	0	0	0	0	0	0	0	0.307
X13	0.423	0	0	0	0	0	0	0	0.423
X12	0.377	0	0	0	0	0	0	0	0.377
X11	0.282	0	0	0	0	0	0	0	0.282

Standardized direct effects (group number 1 - default model)

	RISK	PERF	ECON	SOC	ENVI	ER	DR	PR	SR
PERF	1	0	0	0	0	0	0	0	0
ECON	0	0.576	0	0	0	0	0	0	0
SOC	0	0.64	0	0	0	0	0	0	0
ENVI	0	0.901	0	0	0	0	0	0	0
ER	1	0	0	0	0	0	0	0	0
DR	1	0	0	0	0	0	0	0	0
PR	1	0	0	0	0	0	0	0	0
SR	1	0	0	0	0	0	0	0	0
Y33	0	0	0.606	0	0	0	0	0	0
Y32	0	0	0.567	0	0	0	0	0	0
Y31	0	0	0.788	0	0	0	0	0	0
Y23	0	0	0	0.71	0	0	0	0	0
Y22	0	0	0	0.73	0	0	0	0	0
Y21	0	0	0	0.638	0	0	0	0	0
Y13	0	0	0	0	0.68	0	0	0	0
Y12	0	0	0	0	0.642	0	0	0	0
Y11	0	0	0	0	0.556	0	0	0	0
X41	0	0	0	0	0	0.519	0	0	0
X42	0	0	0	0	0	0.631	0	0	0

	RISK	PERF	ECON	SOC	ENVI	ER	DR	PR	SR
X43	0	0	0	0	0	0.56	0	0	0
X44	0	0	0	0	0	0.512	0	0	0
X45	0	0	0	0	0	0.527	0	0	0
X31	0	0	0	0	0	0	0.669	0	0
X32	0	0	0	0	0	0	0.635	0	0
X33	0	0	0	0	0	0	0.561	0	0
X34	0	0	0	0	0	0	0.606	0	0
X21	0	0	0	0	0	0	0	0.559	0
X22	0	0	0	0	0	0	0	0.526	0
X23	0	0	0	0	0	0	0	0.498	0
X24	0	0	0	0	0	0	0	0.58	0
X15	0	0	0	0	0	0	0	0	0.476
X14	0	0	0	0	0	0	0	0	0.307
X13	0	0	0	0	0	0	0	0	0.423
X12	0	0	0	0	0	0	0	0	0.377
X11	0	0	0	0	0	0	0	0	0.282

Standardized direct effects (group number 1 - default model)

	RISK	PERF	ECON	SOC	ENVI	ER	DR	PR	SR
PERF	0	0	0	0	0	0	0	0	0
ECON	0.576	0	0	0	0	0	0	0	0
SOC	0.64	0	0	0	0	0	0	0	0
ENVI	0.901	0	0	0	0	0	0	0	0
ER	0	0	0	0	0	0	0	0	0
DR	0	0	0	0	0	0	0	0	0
PR	0	0	0	0	0	0	0	0	0
SR	0	0	0	0	0	0	0	0	0
Y33	0.349	0.349	0	0	0	0	0	0	0
Y32	0.327	0.327	0	0	0	0	0	0	0
Y31	0.454	0.454	0	0	0	0	0	0	0

	RISK	PERF	ECON	SOC	ENVI	ER	DR	PR	SR
Y23	0.454	0.454	0	0	0	0	0	0	0
Y22	0.467	0.467	0	0	0	0	0	0	0
Y21	0.409	0.409	0	0	0	0	0	0	0
Y13	0.612	0.612	0	0	0	0	0	0	0
Y12	0.578	0.578	0	0	0	0	0	0	0
Y11	0.501	0.501	0	0	0	0	0	0	0
X41	0.519	0	0	0	0	0	0	0	0
X42	0.631	0	0	0	0	0	0	0	0
X43	0.56	0	0	0	0	0	0	0	0
X44	0.512	0	0	0	0	0	0	0	0
X45	0.527	0	0	0	0	0	0	0	0
X31	0.669	0	0	0	0	0	0	0	0
X32	0.635	0	0	0	0	0	0	0	0
X33	0.561	0	0	0	0	0	0	0	0
X34	0.606	0	0	0	0	0	0	0	0
X21	0.559	0	0	0	0	0	0	0	0
X22	0.526	0	0	0	0	0	0	0	0
X23	0.498	0	0	0	0	0	0	0	0
X24	0.58	0	0	0	0	0	0	0	0
X15	0.476	0	0	0	0	0	0	0	0
X14	0.307	0	0	0	0	0	0	0	0
X13	0.423	0	0	0	0	0	0	0	0
X12	0.377	0	0	0	0	0	0	0	0
X11	0.282	0	0	0	0	0	0	0	0

Execution time summary

Minimization: .102

Miscellaneous: 1.641

Bootstrap: .000

Total: 1.743

มหาวิทยาลัยบูรพา BURAPHA UNIVERSITY

BIOGRAPHY

NAME	Mr. BUNHORNG RATH	
DATE OF BIRTH	August 05, 1988	
PLACE OF BIRTH	Kok Doung village, Puok Commune, Puok District, Siem Reap Province, Cambodia	
PRESENT ADDRESS	Siem Reap Province, Cambodia	
POSITION HELD	2017-Present	Ministry of Economy and Finance, Government Official (Senior)
	2013-2016	Cambodia Post Bank Plc, Head of Regional Branch Operation-managing branch operation for eight branches (last position)
	2009-2013	University of Battambang, Rector's Secretary; Research Consultant and Statistical Advisor; Part-time officer
	2012- 2012	CBIRD Microfinance Co., Ltd, Information Technology Officer
EDUCATION	2012	B.S., Finance and Banking University of Battambang , Cambodia
	2013	B.S., Information Technology Polytechnic Institution of Battambang Province, Cambodia
	2017	M.S., Business Administration University of Battambang , Cambodia
	2022	Ph.D., Candidate in Logistics and Supply Chain Management Burapha University, Thailand
AWARDS OR GRANTS	- Got Ph.D. Scholarship (Fully Funded) in Logistics and Supply Chain Management from Her Royal Highness Princess Maha Chakri Sirindhorn Education Project in 2019 - Got Bachelor Scholarship (100%) in Information Technology from the Royal Government of Cambodia in 2009 - Got Bachelor Scholarship (100%) in Finance and Banking from the Royal Government of Cambodia in 2008	