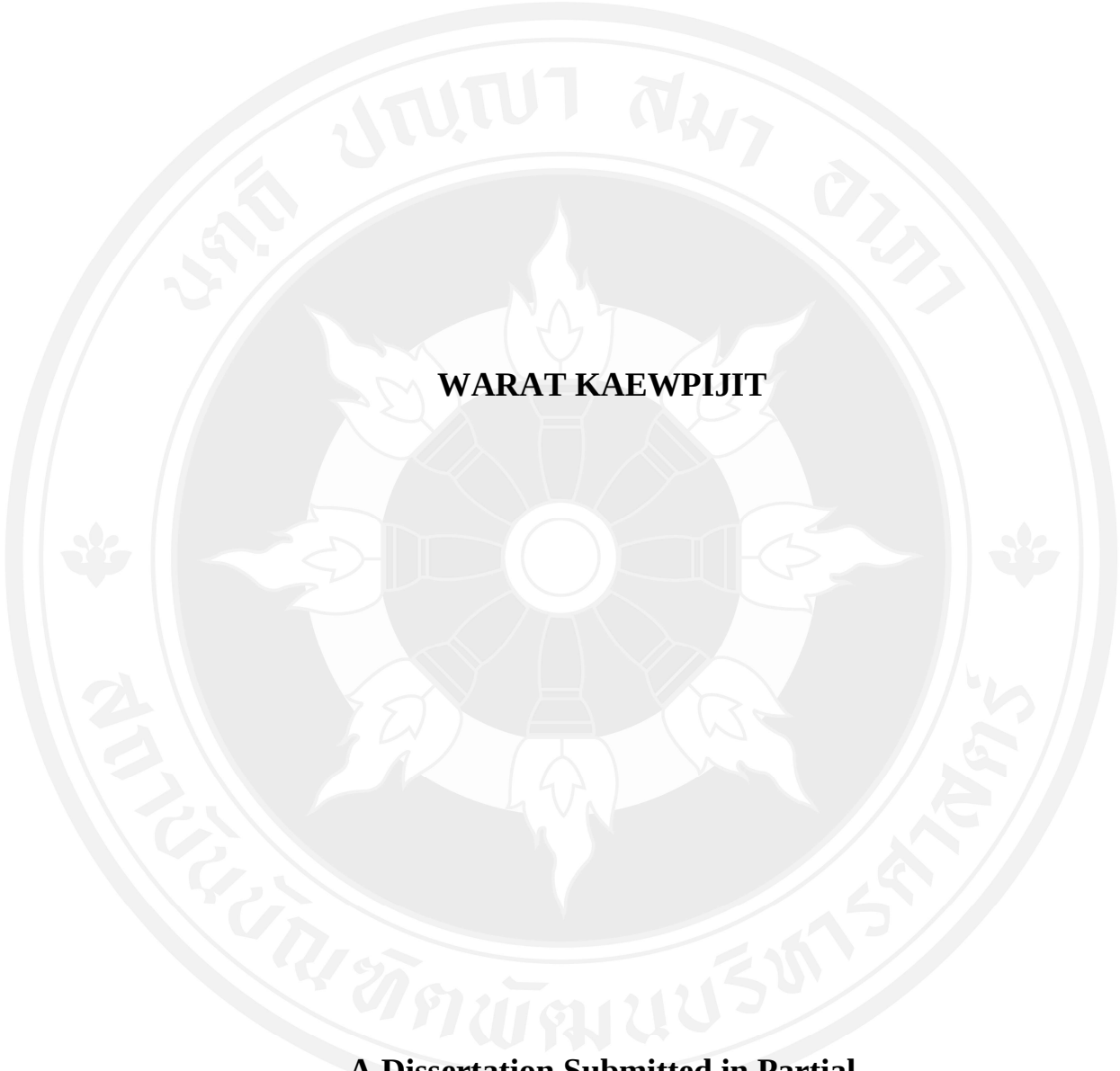


THE FOOD COLD CHAIN PERFORMANCE



WARAT KAEWPIJIT

**A Dissertation Submitted in Partial
Fulfillment of the Requirements for the Degree of
Doctor of Philosophy (Business Administration)
School of Business Administration
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THE FOOD COLD CHAIN PERFORMANCE
WARAT KAEWPIJIT
School of Business Administration

..... Major Advisor
(Associate Professor Viput Ongsakul, Ph.D.)

The Examining Committee Approved This Dissertation Submitted in Partial
Fulfillment of Requirements for the Degree of Doctor of Philosophy (Business
Administration).

..... Committee Chairperson
(Associate Professor Rojanasak Chomvilailuk, Ph.D.)

..... Committee
(Assistant Professor Piya Ngamcharoenmongkol, Ph.D.)

..... Committee
(Associate Professor Pradit Wanarat, Ph.D.)

..... Committee
(Associate Professor Aekkachai Nittayagasetwat, Ph.D.)

..... Committee
(Associate Professor Viput Ongsakul, Ph.D.)

ABSTRACT

Title of Dissertation	THE FOOD COLD CHAIN PERFORMANCE
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The food cold chain is an essential component of preserving the integrity and quality of perishable products, such as fresh produce, seafood, meat, dairy, and frozen food. It serves as the backbone of the food industry, ensuring that these sensitive products are transported, stored, and distributed under optimal temperature conditions, thereby effectively preventing spoilage, maintaining product safety, and preserving nutritional value. However, when the food cold chain is compromised due to inefficiencies, negligence, or inadequate management practices, the consequences are dire and far reaching. Such shortcomings can result in significant loss and the waste of valuable food resources, with grave implications extending to the economy, people's well-being, and the environment. These detrimental effects of an inefficient food cold chain are not isolated but reverberate throughout the system, impacting multiple stakeholders and emphasizing the critical nature of effective cold chain management.

Recognizing the vital role of the food cold chain in preserving perishable goods and the widespread implications of its inefficiency, this dissertation seeks to address a significant gap in the current body of knowledge due to the fact that the field of food cold chain is emerging and still lacking in comprehensive theories and frameworks. To the best of the author's knowledge, previous research has yet to comprehensively examine the relationship between performance factors and cold chain performance by employing structural equation modeling (SEM) to integrate all pertinent performance factors into a single cohesive model. Correspondingly, the primary objective of this dissertation is to develop a robust food cold chain performance model and to conduct an exhaustive analysis of the underlying relationships between the defined constructs. Specifically, this research aims to assess the impact of food cold chain infrastructure, integration, sustainability orientation, value addition, and partners' performance on the overall performance of the food cold chain. This dissertation aspires to offer

stakeholders a comprehensive understanding of the intricate interrelationships among the factors that affect a chain's performance allowing them to develop and implement targeted, effective, and performance-enhancing measures, yielding more advantageous and sustainable outcomes for individual entities and the entire cold chain.

Upon thorough analysis, the findings demonstrate a comprehensive comprehension of the variables that impact the efficacy of the food cold chain. Despite common assumptions, infrastructure, typically viewed as the cornerstone of the food cold chain, does not directly enhance the chain's overall performance. Instead, the analysis highlights its significant indirect impact through value addition. Integration emerged as a critical determinant of performance in this study. It exerts a strong and positive direct relationship with food cold chain performance, particularly when mediated through value addition and partners' performance. It emphasizes integration as the most influential construct in enhancing performance. Notably, while a sustainability orientation does not wield a direct significant effect, it meaningfully influences overall chain performance through the mediating effects of value addition and partners' performance. Our results suggest that the effect of sustainability orientation is substantially channeled through mediating factors. In addition to their extensive direct influence on food cold chain performance, value addition and partners' performance are revealed as crucial mediators influencing the effects of other exogenous constructs on food cold chain performance.

This dissertation contributes to the existing literature by providing a comprehensive model that integrates multiple performance factors, offering new insights into their interrelationships and impacts on food cold chain performance. These insights highlight the essential roles of the aforementioned performance factors and emphasize the necessity of a strategic focus, especially fostering integration, nurturing partnerships, and strategically adding value within cold chain operations.

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TABLE OF CONTENTS

	Page
ABSTRACT.....	iii
ACKNOWLEDGEMENTS.....	v
TABLE OF CONTENTS.....	vii
LIST OF TABLES.....	xi
LIST OF FIGURES	xii
CHAPTER 1 INTRODUCTION	1
1.1 Introduction to Supply Chain Management	1
1.2 Introduction to the Food Cold Chain.....	3
1.3 Importance of the Food Cold Chain	6
1.3.1 Impact on Economics	6
1.3.2 Impact on People's Well-being (Food Demand and Health).....	7
1.3.3 Impact on the Environment	8
1.4 Exploring the Food Cold Chain through the Resource-Based View.....	8
1.5 Significance and Contribution of This Research.....	10
1.6 Organization of This Research	16
CHAPTER 2 LITERATURE REVIEW	18
2.1 Research on Supply Chain Management.....	18
2.2 Research History on the Food Cold Chain	20
2.3 Current Research on the Food Cold Chain.....	21
2.4 Research on the Food Cold Chain's Performance.....	24
2.4.1 Importance of Food Cold Chain Performance and Challenges.....	25
2.4.2 Existing Measures and Metrics for Food Cold Chain Performance.....	25
2.4.3 Factors Affecting the Food Cold Chain's Performance	26
2.5 The Resource-Based View Framework.....	28
2.5.1 Fundamentals of the Resource-Based View: the VRIN Framework	29

2.5.2 The Resource-Based View in Supply Chain Management	32
2.6 Structural Equation Modeling	33
2.6.1 Overview of Structural Equation Modeling	33
2.6.2 Main Components of SEM.....	34
2.6.3 Fundamental Statistics: The Role of Covariance in SEM.....	36
2.6.4 Comparison with Traditional Multivariate Procedures	38
2.6.5 Types of SEM: CB–SEM and PLS–SEM	39
2.6.6 SEM Process.....	40
2.6.7 Underlying Assumptions of Structural Equation Modeling.....	40
CHAPTER 3 CONCEPTUAL MODEL DEVELOPMENT	42
3.1 Conceptual Model Development.....	42
3.1.1 FCC Infrastructure.....	42
3.1.2 FCC Integration.....	43
3.1.3 Sustainability Orientation.....	43
3.1.4 Value Addition	44
3.1.5 Partners' Performance.....	44
3.2 Constructs' Interrelationships and Hypotheses' Development	45
3.2.1 Hypotheses of the Food Cold Chain Infrastructure.....	45
3.2.2 Hypotheses on Food Cold Chain Integration	46
3.2.3 Hypotheses on Sustainability Orientation	48
3.2.4 Hypothesis on Value Addition	50
3.2.5 Hypothesis Regarding Partners' Performance	51
3.3 Research Model.....	51
3.4 Reconsideration and Exclusion of Stakeholders' Interests	54
CHAPTER 4 METHODOLOGY	57
4.1 Research Design and Strategy	57
4.1.1 Philosophical and Methodological Grounding.....	57
4.1.2 Selection and Justification of PLS–SEM as an Analytical Method	57
4.2 Data Collection.....	60

4.2.1 Sample Population and Sampling Method	60
4.2.2 Survey Instrument Design and Deployment	60
4.2.3 Data Collection Procedure and Timeline	60
4.3 Measurement of Variables.....	61
4.3.1 Measurement of Food Cold Chain Infrastructure.....	61
4.3.2 Measurement of Food Cold Chain Integration.....	62
4.3.3 Measurement of Sustainability Orientation.....	63
4.3.4 Measurement of Value Addition	63
4.3.5 Measurement of Partners' Performance	64
4.3.6 Measurement of the Food Cold Chain's Performance	64
4.4 Implementation of PLS–SEM	71
4.4.1 Model Specification	71
4.4.2 Model Estimation and Assessment.....	72
4.5 Data Analysis and Interpretation	73
4.5.1 Validity and Reliability Measures	73
4.5.2 Interpreting the Structural Model	74
4.5.3 Considering Model Fit and Goodness-of-Fit Measures	76
4.6 Ethical Considerations	76
4.7 Limitations and Assumptions	77
CHAPTER 5 DATA ANALYSIS AND RESULTS	78
5.1 Data and Analytical Tools Employed.....	78
5.1.1 Source of Data	78
5.1.2 Analytical Tool.....	79
5.1.3 Respondent Demographics.....	79
5.2 Validity and Reliability Measures	81
5.2.1 Reliability Measures.....	81
5.2.2 Convergent Validity Measures	82
5.2.3 Discriminant Validity Measure	85
5.2.4 Multicollinearity Assessment	90

5.3 Interpretation of the Structural Model	92
5.3.1 Explanation of the Structural Model	92
5.3.2 Analysis of Path Coefficients	92
5.3.3 Understanding of Effect Sizes	100
5.3.4 Evaluation of R-squared Values	101
5.4 Consideration of Model Fit and Goodness-of-Fit Measures	101
5.5 Special Case: Development of the Pilot Model	102
CHAPTER 6 DISCUSSION AND IMPLICATIONS	111
6.1 Key Findings on the FCCP Model	111
6.2 Relevance to the Thai Food Cold Chain	113
6.3 Alignment of Findings with the Literature	116
6.4 Practical Implications	119
6.5 Future Research Directions	121
CHAPTER 7 CONCLUSION	123
BIBLIOGRAPHY	126
BIOGRAPHY	150

LIST OF TABLES

	Page
Table 4.1 List of Measures.....	65
Table 5.1 Respondent Demographic Profile	80
Table 5.2 Reliability Measures of the FCCP Model.....	82
Table 5.3 Average Variance Extracted (AVE) of the FCCP Model.....	83
Table 5.4 Outer Loadings of the FCCP Model	83
Table 5.5 Initial Assessment of the Discriminant Validity of the FCCP Model	86
Table 5.6 Final Assessment of Discriminant Validity of the FCCP Model.....	87
Table 5.7 Cross-Loadings After Indicators' Removal from the FCCP Model.....	89
Table 5.8 Variance Inflation Factor (VIF) of the FCCP Model	91
Table 5.9 Direct Effects of the FCCP Model.....	95
Table 5.10 Indirect Effects of the FCCP Model	96
Table 5.11 Specific Indirect Effects of the FCCP Model	97
Table 5.12 Total Effects of the FCCP Model	98
Table 5.13 Hypotheses Testing Results of the FCCP Model.....	99
Table 5.14 F-Square of the FCCP Model	101
Table 5.15 R-Square of the FCCP Model.....	101
Table 5.16 Model Fit Summary of the FCCP Model.....	102
Table 5.17 Respondents' Demographic Profile of the Pilot Model.....	104
Table 5.18 Construct Reliability and Validity of the Pilot Model.....	106
Table 5.19 Outer Loadings of the Pilot Model	106
Table 5.20 Fornell–Larcker Criterion of the Pilot Model.....	108
Table 5.21 R-Square of the Pilot Model	108
Table 5.22 Model Fit Summary of the Pilot Model.....	108
Table 5.23 Hypotheses Testing Result of the Pilot Model	110

LIST OF FIGURES

	Page
Figure 2.1 Components of SEM	36
Figure 2.2 Example of SEM	38
Figure 3.1 The Food Cold Chain Performance Model	53
Figure 5.1 The Food Cold Chian Performance Model (Pilot)	103

CHAPTER 1

INTRODUCTION

1.1 Introduction to Supply Chain Management

Supply chain management (SCM) is a complex and multifaceted discipline that plays a crucial role in efficiently integrating and coordinating supply chain members, from suppliers to retailers. According to Mentzer et al. (2001), SCM involves the systematic coordination of essential business functions within a company and across businesses in the supply chain to improve long-term performance. The primary objective of SCM is to ensure the smooth and effective transformation and distribution of products throughout the entire supply chain, from the sourcing of raw materials to the final market distribution. By emphasizing the interdependence between supply chain members and promoting collaboration, SCM aims to enhance the overall efficiency and performance of the supply chain (Narasimhan & Kim, 2002; Shin, Collier, & Wilson, 2000).

A fundamental benefit of effective SCM is minimizing costs and fulfilling service-level requirements. By implementing SCM principles and practices, companies can optimize their operational processes, streamline workflows, and eliminate unnecessary expenses, leading to cost reduction and increasing profitability (Rodrigue, Comtois, & Slack, 2013; Shukla & Jharkharia, 2013; Simchi-Levi, Kaminsky, Simchi-Levi, & Shankar, 2008). Furthermore, SCM enables companies to meet the demands and expectations of customers by ensuring that products are available in the right quantity, at the right time, and in the right place, thus enhancing customer satisfaction and loyalty.

In today's highly competitive business landscape, SCM is recognized as a crucial practice that can provide companies with a competitive advantage and improve organizational performance. Through appropriate and efficient SCM practices,

businesses can enhance their performance in terms of agility, responsiveness, and flexibility, allowing them to adapt quickly to market changes and customer preferences (Janvier-James, 2012; Li, Ragu-Nathan, Ragu-Nathan, & Subba Rao, 2006; Rungtusanatham, Salvador, Forza, & Choi, 2003). Companies can achieve operational excellence and drive sustainable growth by continuously improving their supply chain processes and collaborating with supply chain partners.

It is vital for firms to recognize that collaboration among supply chain members is crucial for achieving the desired performance of their supply chains. No single organization can effectively manage its entire supply chain alone. Instead, successful SCM requires cooperation, information sharing, and coordinated efforts among all stakeholders (Dania, Xing, & Amer, 2018; Verghese, Lewis, Lockrey, & Williams, 2015). By working together, supply chain members can raise visibility, reduce risks, and optimize the flow of goods, services, and information throughout the supply chain network.

The significance of refining supply chain efficiency is recognized by firms globally because it directly contributes to maintaining a competitive advantage. Organizations can strengthen their market positions and differentiate themselves from competitors by reducing costs, improving flexibility, enhancing product quality, and ensuring customer satisfaction (Li et al., 2006; Mellat-Parast, 2013). The continuous pursuit of supply chain efficiency is driven by global market dynamics and the need to respond to changing customer expectations in a rapidly evolving business environment.

Over the decades, the field of SCM has garnered extensive attention from researchers and practitioners across disciplines. Supply chain performance stands out as a particularly crucial area of interest, emphasizing the measurement and enhancement of supply chain efficiency. The advent of innovative technologies has revolutionized how information is collected, integrated, and shared among supply chain partners, leading to significant advancements in the evaluation of supply chain performance. By closely monitoring key performance indicators and streamlining processes, organizations can achieve operational excellence, meet customer expectations, and gain a competitive advantage in the dynamic business landscape. Ultimately, prioritizing supply chain performance empowers organizations to boost customer satisfaction, optimize resource allocation, and enhance overall profitability.

Researchers have classified studies in the field of supply chain performance measurement into eight categories, reflecting different disciplinary areas and impact factors. These categories include accounting; sector studies; general management; economics, econometrics, and statistics; sustainability; information management; operations research and management; and operations technology and management (Maestrini, Luzzini, Maccarrone, & Caniato, 2017). Despite significant progress in supply chain performance measurement, there is still ongoing research and exploration in areas such as framework development, empirical cross-industry studies, and the adoption of performance measurement systems. These research areas hold the potential for developing partnerships, enhancing collaboration, fostering agility and flexibility, improving information productivity, and achieving business excellence metrics (Arzu Akyuz & Erman Erkan, 2010).

In recognition of the interconnections between supply chain performance and consumer behavior, researchers have conducted studies that integrate these fields. These studies investigate how the structure and dynamics of the supply chain impact both performance and consumer surpluses. By understanding consumer preferences and aligning supply chain activities accordingly, companies can improve their supply chain performance and better meet the needs and expectations of their customers (Wang, Wang, & Lai, 2019; Xue, Caliskan Demirag, & Niu, 2014). Furthermore, studies have explored the efficient utilization of customer responses in refining supply chains' performance, highlighting the importance of customer-centric approaches to SCM (Kotzab, 1999; Wang et al., 2019; Xue et al., 2014).

In addition to its critical role in integrating and optimizing supply chains, effective SCM holds particular importance in certain industries, such as the food sector. One area of focus is the food cold chain, which plays a vital role in preserving the quality and safety of perishable goods throughout their journey from production to consumption.

1.2 Introduction to the Food Cold Chain

Because various researchers tend to devise their own explanations of *cold chain*, there seems to be little to no consensus on its definition. For instance, Rodrigue et al.

(2013) defined the *cold chain* as “the transportation of temperature-sensitive products along a supply chain through thermal and refrigerated packaging methods and the logistical planning to protect the integrity of this shipment.” The *cold chain* can also be described as “a post-production supply chain for temperature-sensitive, perishable goods that is specifically designed to keep these products in a conditioned environment, for example, within an optimal temperature and humidity range, in order to guarantee product safety, preserve value, and maximize commercial potential” (Bremer, 2018). Likewise, Singh, Gunasekaran, and Kumar (2018) defined the *cold chain* as “the process of planning, implementing, and controlling the flow and storage of perishable goods, related services, and information to enhance customer value and ensure low costs.” In short, Joshi, Banwet, and Shankar (2011) stated, “A cold chain comprises equipment and processes that keep perishable products under a conditioned environment.” Similarly, Shabani, Torabipour, and Saen (2015) described the *cold chain* as a particular supply chain whose activities and processes ensure temperature control for perishable products. Hence, *cold chain* management is the implementation of SCM for perishable products with characteristic features and activities (Bogataj, Bogataj, & Vodopivec, 2005; Kuo & Chen, 2010). Although multiple definitions of the cold chain exist, this study describes the *cold chain* as follows:

“The *cold chain* is the process of planning, implementing, and controlling the flow and storage of temperature-sensitive perishable products along the supply chain through temperature-controlled methods to maintain the integrity of the product.”

Perishable products encompass a wide range of goods, including agricultural products, seafood, frozen and chilled food, and pharmaceuticals. Guike Liu, Hu, Yang, Xia, and Lim (2020) categorized these perishable products into five main categories: 1) fruits and vegetables, 2) bakery and confectionary, 3) dairy and frozen desserts, 4) fish and seafood, and 5) drugs and pharmaceuticals. Later, Shashi, Centobelli, Cerchione, and Ertz (2020) further combined food products into one category and divided the cold chain into two main fields: the food cold chain (FCC) and the pharmaceutical cold chain (PCC). The FCC focuses explicitly on the transportation and storage of food products, aiming to maintain their optimal conditions and thereby preserve their safety and

quality (Cerchione, Singh, Centobelli, Shabani, & Cerchione, 2018; Hertog, Uysal, McCarthy, Verlinden, & Nicolai, 2014). Consequently, *food cold chain management* (FCCM) can be defined as a set of supply chain practices aimed at preserving an appropriate atmosphere for perishable food products and preventing microbial spoilage (Joshi et al., 2011; Patidar, Shukla, & Sukhwani, 2022). Therefore, the *food cold chain* can be defined as follows:

“The food cold chain is a specialized subset of the cold chain that encompasses the process of planning, implementing, and controlling the flow and storage of perishable food products using temperature-controlled methods throughout the supply chain with the primary objective of ensuring the integrity of the product from the point of origin to the consumer.”

According to Shashi et al. (2020), the FCC is considered less mature than the PCC. With better transportation schedules and a higher level of automation, the PCC generally exhibits higher efficiency than the FCC in terms of product quality, packaging integrity, and punctuality. The FCC also must have a certain level of flexibility, since food demand can vary due to changes in customers' tastes, preferences, and lifestyles (Aramyan, Oude Lansink, van der Vorst, & van Kooten, 2007). Additionally, the FCC significantly impacts people's well-being, economics, and the environment.

The FCC's activities start at the farm level and extend to the customer level, which can be divided into three stages: 1) the agricultural production stage at the farm level, 2) the postharvest stage, which ranges between harvesting and human consumption, and 3) the consumer stage, when the product reaches buyers (Liu, 2014). While the first stage can be considered irrelevant to the FCC, most researchers have focused on the latter two stages. According to James and James (2010), the overall process of the cold chain includes chilling and freezing goods, their subsequent refrigeration, the refrigeration of goods during the postharvest stage, transportation, retail distribution, and home storage. Likewise, Zhao, Liu, Tian, Yan, and Wang (2018) categorized the process of the FCC into six stages: precooling, freezing, storage, transportation, distribution, and home storage.

Starting from the postharvest stage, the FCC requires a variety of infrastructures, such as pre-cooling facilities, cold warehouses, refrigerated vehicles,

containers, packaging, and traceability measurement tools (Joshi, Banwet, & Shankar, 2009; Montanari, 2008).

1.3 Importance of the Food Cold Chain

The FCC plays an absolutely critical and non-negotiable role in preserving the integrity of and ensuring the highest-quality perishable products, including fresh produce, seafood, meat, dairy products, frozen food, and many others (Joshi et al., 2011). Its significance cannot be overstated, as it is the backbone of the entire perishable goods industry, ensuring that these delicate and time-sensitive products are transported, stored, and distributed under optimal temperature conditions. In doing so, the FCC effectively prevents spoilage, maintains product safety, and preserves nutritional value, guaranteeing that consumers receive only the finest and most reliable products. However, when the FCC is subjected to inefficiencies, negligence, or inadequate management practices, the consequences are dire and far reaching. One of the most devastating outcomes is the significant loss and waste of valuable food resources, posing grave implications for the economy, people's well-being, and the environment. The detrimental effects of an inefficient FCC reverberate throughout the entire system and impact multiple stakeholders. The effects of inefficient FCCs can be categorized into three primary areas influenced by an ineffective FCC: the economy, people's well-being, and the environment, each of which will be explored in more detail below.

1.3.1 Impact on Economics

Food loss and waste within the cold chain inflicts severe economic repercussions on a global scale. Astonishingly, approximately 30 percent of the total food produced, equivalent to a staggering 1.3 billion tons, is wasted annually due to inefficiencies in the FCC (Cerchione, Singh, et al., 2018). This immense amount of waste translates into a shocking monetary loss of approximately \$990 billion each year (Food and Agriculture Organization, 2013). This wastage represents the enormous squandering of valuable resources, resulting in a significant drain on the global economy. To illustrate the economic toll on a regional level, let us consider China, where inefficient cold chain practices lead to an annual wastage of around 370 million

tons of fruits and vegetables, with a value estimated at about \$10 million (Shabani, Saen, & Torabipour, 2012). This tremendous economic loss is primarily attributable to poor monitoring systems, ineffective cold chain facilities, and logistical deficiencies. To put it bluntly, this is an utterly unacceptable and unsustainable situation.

By effectively mitigating food waste and loss within the cold chain, substantial economic gains can be achieved. For instance, a mere 1 percent reduction in food waste in Sub-Saharan Africa could yield an annual economic benefit of \$40 million (The World Bank, 2011). These financial resources could be redirected toward improving infrastructure, investing in technological advancements, and uplifting local communities, thus creating a more prosperous and sustainable society.

1.3.2 Impact on People's Well-being (Food Demand and Health)

The ramifications of an inefficient FCC extend far beyond the realm of economics. It directly affects people's well-being, jeopardizing their access to safe and nutritious food. As the global population is expected to reach 9.7 billion by 2050, there will be an unprecedented surge in food demand (UN DESA, 2019). This places immense pressure on the FCC, which serves as the lifeline for distributing food worldwide. In essence, the FCC functions as a pivotal "global food village," connecting producers to consumers across the globe (Cerchione, Singh, et al., 2018).

However, when the cold chain operates inefficiently, it results in an alarming amount of food waste, approximately 1.3 billion tons per year. It is difficult to comprehend the sheer magnitude of this wastage, especially considering the millions worldwide suffering from hunger and malnutrition. Over 820 million people globally are currently experiencing hunger (Food and Agriculture Organization, 2019). By reducing food loss and waste within the cold chain, a substantial portion of this wasted food could be redirected to feed those in need, thereby addressing the pressing issue of food insecurity.

Moreover, the mismanagement of the FCC has severe health implications. Inadequate temperature control and monitoring can lead to the proliferation of microbial hazards, resulting in foodborne illnesses (Jol, Kassianenko, Wszol, & Oggel, 2007; Rediers, Claes, Peeters, & Willems, 2009; Uçar & Özçelik, 2013). Such illnesses pose a significant threat to public health, potentially leading to severe consequences,

including hospitalizations and, in extreme cases, even the loss of life. It is imperative to recognize that the efficiency and reliability of the FCC directly impacts people's health and well-being.

1.3.3 Impact on the Environment

The environmental implications of an inefficient FCC are substantial and cannot be ignored. Food waste from cold chain failures significantly contributes to global greenhouse gas emissions. Shockingly, it is estimated that food waste accounts for approximately 3.3 billion tons of CO₂ emissions annually (Food and Agriculture Organization, 2013). This colossal amount of greenhouse gas emissions intensifies the adverse effects of climate change and places a heavy burden on our planet.

Additionally, the energy-intensive nature of cold chain activities, particularly temperature control in warehouses, contributes to significant carbon emissions from power plants, surpassing those associated with other supply chains. The leakage of hydrofluorocarbons (HFCs), used as refrigerants in cold chain systems, exacerbates the problem because HFCs are potent greenhouse gases (Bozorgi, 2016; James & James, 2010).

It is imperative that we address these environmental concerns and take immediate action to implement sustainable practices within the FCC. By improving energy efficiency, reducing refrigerant leaks, and embracing environmentally friendly technologies, we can mitigate the carbon footprint associated with the cold chain. Such measures will contribute to our planet's preservation and align with global efforts to combat climate change and create a more sustainable future.

1.4 Exploring the Food Cold Chain through the Resource-Based View

In the 1980s, the resource-based view (RBV) emerged as a strategic management theory that has since become a seminal concept in the field. It provides valuable insights into why some firms outperform others in competitive markets, emphasizing the importance of internal resources and capabilities in achieving a competitive advantage. The RBV has been widely applied and has yielded significant results, playing a vital role in shaping modern strategic management practices.

Essentially, the theory posits that a firm's resources are the main drivers of its competitive advantage, enabling it to create value for customers and maintain superior performance over time (Wernerfelt, 1984). It also offers a systematic approach to evaluating a firm's strategic resources and their contribution to achieving and sustaining a competitive advantage. According to Barney (1991), a firm's strategic resources must possess specific attributes to generate a competitive advantage for the firm, including being valuable, rare, inimitable, and non-substitutable. Utilizing the RBV theory, firms can identify their unique resources, capabilities, and competencies and assess how these resources enable them to outperform their competitors.

Several studies have explored the intersection of the RBV and SCM, offering valuable insights into the mechanisms through which firm-specific resources contribute to supply chain performance (Chae, Olson, & Sheu, 2014; Gold, Seuring, & Beske, 2010; Huo, Han, & Prajogo, 2016; Rungtusanatham et al., 2003; Seggie, Kim, & Cavusgil, 2006; Wu, Yeniyurt, Kim, & Cavusgil, 2006; Yu, Chavez, Jacobs, & Feng, 2018). According to the RBV, firms' competitive advantages stem from their ability to leverage unique and valuable resources and capabilities. This perspective suggests that firms can enhance their performance by strategically managing critical resources, such as infrastructure, technology, and human capital. For instance, firms that invest in state-of-the-art temperature-controlled storage facilities or implement advanced tracking and monitoring systems may gain a competitive edge in ensuring product quality and timely delivery. Additionally, the theory emphasizes the importance of building capabilities that are difficult for competitors to imitate or substitute, such as supply chain integration, value addition, and sustainability orientation, which further optimize the cold chain. For instance, enhanced supply chain integration helps facilitate the exchange of information, joint decision making, and risk pooling, ultimately leading to better chain performance.

While the RBV has offered valuable insights into SCM, its application in the FCC reveals certain limitations. The theory primarily focuses on how individual firms can gain a competitive advantage by strategically utilizing resources and capabilities that certainly enhance food cold chain performance (FCCP). However, it is important to remember that the FCC is an interdependent system in which all members play a crucial role in contributing to the chain's performance. Targeting a single firm, while

undoubtedly necessary, has proven insufficient. Hence, while the strategic utilization of resources and capabilities is crucial, solely relying on the RBV may not be adequate, as it fails to account for all the factors influencing the performance of the FCC, such as the impact of partner performance, regulatory compliance, technological advancements, or market dynamics.

Hence, there is a need to develop a more tailored framework that effectively addresses the limitations of the traditional RBV theory and other SCM theories, particularly concerning the cold chain. This newly developed framework, called the *food cold chain performance model*, will be a conceptual model that targets FCCP. The FCCP model should consider the unique challenges and requirements of managing perishable food products by integrating insights from both the RBV and the field of cold chain management. Through this integration, the conceptual model can provide a comprehensive approach to identifying, managing, and leveraging resources and capabilities, ultimately enhancing cold chain performance and achieving sustainable competitive advantages.

1.5 Significance and Contribution of This Research

Since the inception of the FCC in 1995, achieving superior food cold chain performance has been a primary objective for researchers and practitioners alike. Various methodologies have been utilized to achieve this goal, including the identification of bottlenecks, the development of measurement frameworks, and the exploration of performance relationships with relevant factors. However, there has been limited exploration of performance from a combination of FCCM perspectives. For instance, Cai, Chen, Xiao, and Xu (2010) conducted a study on maintaining product freshness by analyzing the efforts of producers and distributors. They created an optimized model that enhanced decision making for both parties. Ahumada and Villalobos (2011a, 2011b) developed two optimization models that improved the cold chain's performance at both operational and tactical levels. Moreover, technology has been utilized to improve performance, as demonstrated in Kuo and Chen's (2010) development of a logistics service model based on a multi-temperature joint distribution

system, which enabled logistics providers to gain a competitive edge in thermal production.

While researchers have addressed performance improvement from various perspectives, they rarely incorporate multiple performance factors into their studies. For instance, Fattahi, Nookabadi, and Kadivar (2013) analyzed Indian meat cold chain characteristics and performance and then developed a performance measurement model using a combination of literature review and Delphi–TOPSIS approaches. They discerned 19 performance indicators, which were categorized into four dimensions: financial, customer, internal process, and innovation and learning. Similarly, Joshi et al. (2011) proposed a benchmarking framework for evaluating a firm’s cold chain performance using the Delphi–AHP–TOPSIS method. This framework comprises 27 indicators in seven categories: 1) Management and Strategy, 2) Infrastructure, 3) Processes, 4) Human Resources, 5) Customer Service, 6) Financial Performance, and 7) Regulatory Compliance. However, the proposed framework for evaluating cold chain performance has some limitations.

The aforementioned performance models also have limitations. For example, the Delphi method has high expert dependency, which could lead to the result being biased due to the chosen experts’ opinions (Linstone & Turoff, 1975). The model can also have serious reliability issues, as consistency in experts’ judgment is vital during the AHP process, which may not always be guaranteed (Saaty, 1990). In addition, the process is also time consuming, since it involves multiple rounds of questionnaires for the Delphi method and highly complex implementation for AHP and TOPSIS (Skulmoski, Hartman, & Krahn, 2007).

While previous studies have made valuable contributions to understanding food cold chain performance, they often overlook the underlying theoretical foundations that could provide a more comprehensive framework for analysis. Most of these studies concern practical aspects, such as utilizing technology to improve performance or developing production and operation planning models. This emphasis on practicality is largely due to the nature of the SCM field, which prioritizes immediate, actionable solutions to address real-world challenges. Consequently, the focus on practical applications ensures that findings and recommendations can be directly utilized to enhance supply chain operations and efficiency. However, this approach often leaves

theoretical exploration and development underemphasized, which could limit the depth and scope of understanding in the field.

Given the practical orientation of existing studies, it is crucial to explore theoretical perspectives that can provide deeper insights and more robust frameworks. One such theoretical perspective is the RBV, which is one of the most prominent frameworks in the field of management and offers unique insights into how firms can achieve and sustain a competitive advantage through the strategic management of their resources and capabilities. The existing body of literature pertaining to the RBV and its correlation with supply chain performance underscores the theoretical framework of the theory and its relevance across diverse industries. Nevertheless, there is a notable gap in the literature regarding the theoretical foundations of the RBV in the context of supply chain performance, particularly within the FCC domain. This gap underscores the need for research that delves deeper into the intersection of the RBV and food cold chain performance to provide theoretical insights and practical implications for the food industry.

Hence, the RBV framework can serve as the theoretical foundation for the development of the conceptual model, addressing the limitations of traditional SCM theories, particularly in managing perishable food products within the cold chain. Unlike existing SCM theories, the newly developed model will integrate insights from both the RBV and FCCM to offer a more tailored framework that considers the unique challenges and requirements of the FCC. By leveraging the principles of the RBV, the newly developed model aims to help firms identify and strategically manage resources and capabilities essential for optimizing cold chain performance and achieving sustainable competitive advantages.

While the RBV offers valuable insights into enhancing food cold chain performance by emphasizing the strategic utilization of resources and capabilities, a gap remains in how to operationalize these insights effectively due to the complex nature of supply chains. This complexity arises from the interactions between performance factors and their combined impact on the cold chain, which traditional methodologies often struggle to address comprehensively. This is where the structural equation model (SEM) becomes crucial. SEM provides a robust method for exploring the complex relationships between performance factors and their impacts on cold chain

performance. Unlike traditional methodologies, SEM allows the analysis of latent constructs, enabling researchers to delve deeper into the underlying mechanisms driving performance. SEM also offers several other advantages in analyzing structural relationships. First, it allows the modeling of complex relationships, including indirect and mediating effects. SEM also can handle many variables and relationships simultaneously. Finally, the most distinguishing feature of SEM lies in its ability to analyze latent variables, which are not directly observed but inferred from other measurable variables. For example, Qazi, Moazzam, Ahmed, and Raziq (2022) applied SEM to analyze the relationship between green in-store operations and the sustainability performance of the fresh food chain. Similarly, Hsiao and Huang (2016) investigated the effects of power, quality uncertainty, and business strategy on time–temperature information sharing among FCCs. SEM was often applied to many other contexts, such as exploring the relationship between internal processes and organizational growth on three aspects of sustainability, including environmental, economic, and social, in the context of the vaccine cold chain (Mukherjee, Baral, Chittipaka, Pal, & Nagariya, 2023). Therefore, using SEM can be advantageous in assessing the performance of the FCC.

Through an investigation of the model using SEM, we can gain insight into the intricate relationships among performance factors. First, the path coefficients provide information regarding the strength and direction of the relationships between the constructs in the model. Through this information, the effects of each performance construct on each other and food cold chain performance can be analyzed to determine whether the effect is positive or negative, or there is or no relationship. Moreover, the statistical significance of the relationship can be investigated through bootstrapping. SEM also provides the effect size (f-square), which determines the substantive significance of a path coefficient; the larger the effect size, the more meaningful the relationship. Briefly, while path coefficients provide information on the direction and strength of the relationship, the effect size reveals the importance of that relationship in a substantive sense. In addition to exploring the relationship among constructs, SEM provides information regarding the strength of the relationship of indicators on its constructs. This valuable insight can be utilized to improve each performance construct and, ultimately, food cold chain performance. Through the use of SEM, the reliability

and validity of the model can be ensured through the investigation of various statistics, such as cross-loadings, composite reliability, Cronbach's alpha, and average variance extracts.

To the best of the author's knowledge, no previous research has examined the relationship between performance factors and cold chain performance using structural equation modeling to incorporate all performance factors into the model. Thus, it is crucial to develop a food cold chain performance model, conduct a thorough analysis of the underlying relationships, and develop measures to enhance performance. Employing SEM, this dissertation aims to examine the impact of FCC infrastructure, integration, stakeholders' interest, sustainability orientation, value addition, and partners' performance on food cold chain performance. Using the RBV as a foundational theory, this study identifies and explores the resources and capabilities that constitute these critical performance factors. Through empirical analysis and theoretical exploration, this research seeks to provide actionable insights for stakeholders to strategically allocate resources and enhance capabilities that will help optimize performance and achieve sustainable competitive advantages within the FCC. In addition, by comprehensively grasping the interrelationships among factors that impact the chain's performance, stakeholders can develop and implement the necessary performance-enhancing measures. This will produce more advantageous results for themselves and the entire chain.

The proposed conceptual model was developed through an extensive literature review and discussion with both academics and practitioners. Building on the RBV theory and the food cold chain performance framework proposed by Cerchione, Singh, et al. (2018), this research incorporates performance factors identified from both literature sources and the RBV. By synthesizing insights from multiple studies, this study proposes a conceptual model that depicts the relationship between these relevant factors and cold chain performance (Aramyan et al., 2007; Fattahi et al., 2013; Joshi et al., 2011; Rao & Holt, 2005). This food cold chain performance model comprises seven constructs, which are latent variables for performance factors, and are divided into three levels. The chosen constructs were derived from an extensive literature review, especially previous empirical research, on crucial aspects that impact the food cold chain's performance.

The first layer, exogenous constructs, is the food cold chain's infrastructure, integration, stakeholders' interest, and sustainability orientation. These constructs served as independent variables in the model because they were not influenced by others. FCCs' infrastructure is one of the most significant aspects because it serves as the foundation of all operations. A poorly developed infrastructure can drastically reduce performance (Sindhwani, Mittal, Singh, Aggarwal, & Gautam, 2019). For example, Jayaram, Vickery, and Droge (2000) highlighted that information system infrastructures can significantly impact certain aspects of supply chain performance. Likewise, the literature has proven that internal and external integration is crucial for enhancing the performance of any type of supply chain, including a cold chain (Chang, Ellinger, Kim, & Franke, 2016; Jie, Parton, & Cox, 2013; Sharma & Pai, 2015). The integration of the FCC encompasses not only the physical level but also information flows across the chain. Stakeholders' interests are also considered a crucial building block for any supply chain because stakeholders can influence any activities in the chain. Failing to recognize stakeholders' interests can lead to failed operations due to conflict among chain members. According to stakeholder theory, prioritizing and managing stakeholders' interests can lead to greater long-term success for a business (Freeman, 2010). Last, the sustainability orientation construct was chosen because of its significant effect on the performance of the chain. In the past decade, researchers have proven that sustainability practices positively affect supply chain performance through several means (Klassen & Vereecke, 2012; Mani, Gunasekaran, & Delgado, 2018; Rao & Holt, 2005).

The second level of the FCCP model comprises value addition and partners' performance. These constructs serve as mediating constructs by bridging the effect of exogenous constructs with endogenous constructs in the last layer. Value addition was chosen as a construct for the second layer, since it represents one of the primary goals of the FCC: to produce and preserve the product that meets customer demands, adding value to products. Value-adding activities were influenced by the constructs of all the first layers. For example, studies have shown that sustainability practices can impact various aspects of the supply chain, including new product design, better production processes, and other activities within the chain (Aikenhead, Farahbakhsh, Halbe, & Adamowski, 2015; Klewitz & Hansen, 2014). Similarly, partners' performance was

chosen because it was affected by the first layers' constructs and significantly impacted the performance of the FCC. Members' performance is considered an essential predictor of overall SC performance because they can significantly impact each other (Shashi, Singh, Centobelli, & Cerchione, 2018).

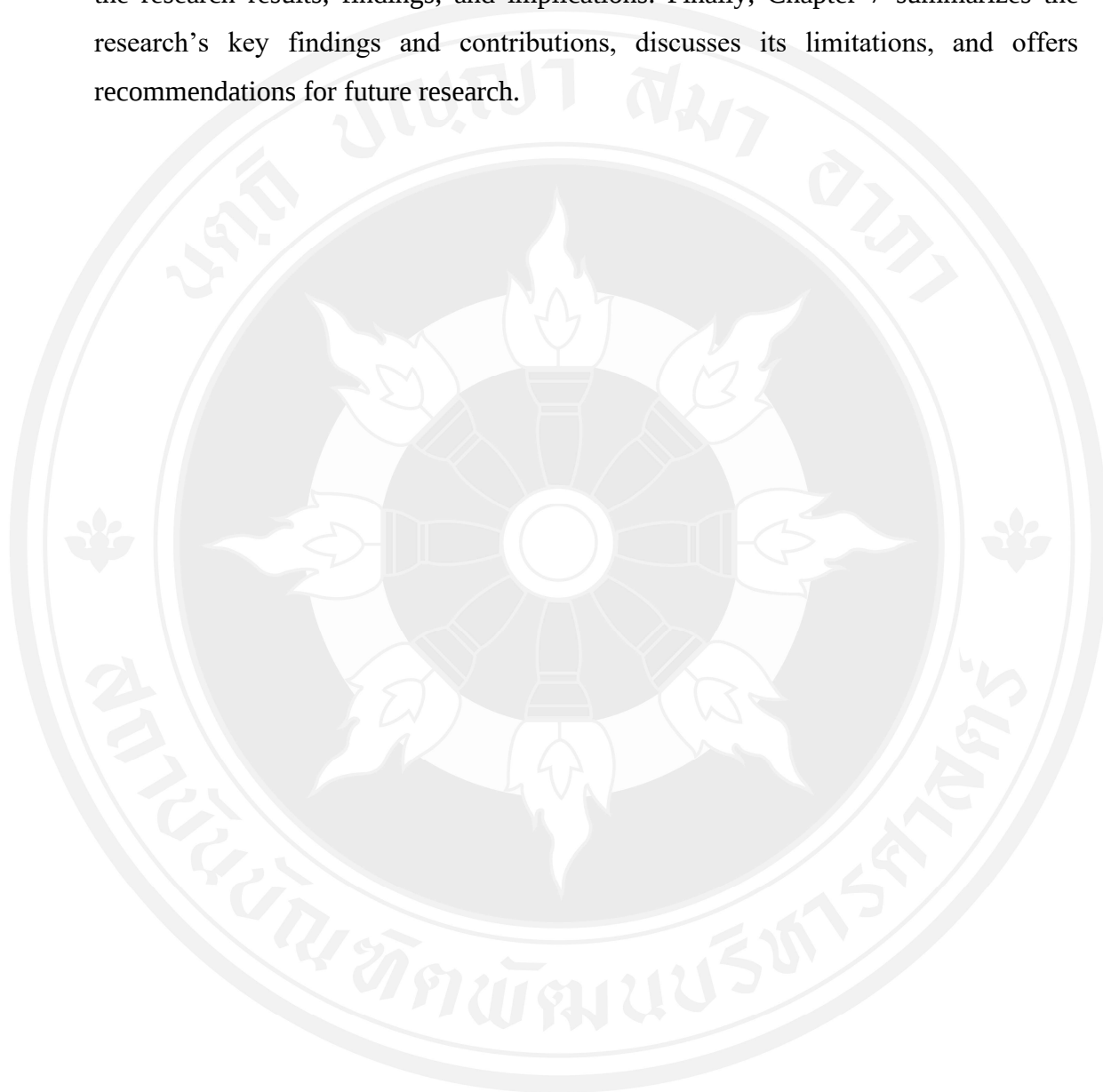
Finally, the last layer, the endogenous construct, is the outcome of this FCCP model, which represents food cold chain performance. The food cold chain performance was influenced by other constructs in the model. For instance, FCC integration allows members to share resources, enabling firms to better serve customers and gain a competitive advantage, ultimately resulting in heightened chain performance (Cagliano, Caniato, & Spina, 2006).

The findings of the FCCP model have markedly contributed to our understanding of how performance factors affect the performance of the FCC. Through SEM, the intricate dependencies among performance factors and their influence on the food cold chain's performance were investigated. The insights from this research can pave the way for further exploration in this field, and the findings provide strong empirical evidence supporting the existing frameworks for FCCM. Through the examination of various performance factors, this research aims to revolutionize the management of perishable products in the cold chain. By gaining valuable insights from this study, practitioners at any stage of the FCC will be better equipped to make informed decisions, develop effective strategies, and implement targeted measures that will significantly improve overall performance. This improvement will ensure that the integrity of food products is maintained throughout the chain, leading to reduced food waste and enhanced food safety. Additionally, this will contribute to securing global food demand and enhancing the food industry while reducing environmental impact and achieving a sustainable future.

1.6 Organization of This Research

The remainder of this dissertation is organized into seven chapters. Chapter 2 offers a comprehensive review of the existing literature on the topic of food cold chain performance, along with relevant theories that will be utilized throughout the research. Chapter 3 provides the development of a conceptual model that depicts the relationship

between food cold chain performance and its relevant factors. Chapter 4 supplies a detailed explanation of the methodology employed in this research. In Chapter 5, a detailed analysis of the research is presented, highlighting the thoroughness and attention to detail that has gone into this study. Chapter 6 offers valuable insights into the research results, findings, and implications. Finally, Chapter 7 summarizes the research's key findings and contributions, discusses its limitations, and offers recommendations for future research.



CHAPTER 2

LITERATURE REVIEW

2.1 Research on Supply Chain Management

In an increasingly competitive global market, SCM has asserted itself as a critical determinant of firm success (Baltacioglu, Ada, Kaplan, Yurt And, & Cem Kaplan, 2007). As described by Hugos (2011), SCM covers the coordination and management of all supply chain activities with the objective of creating net value, building a competitive infrastructure, synchronizing supply with demand, and measuring global performance. The business landscape has witnessed a paradigm shift from firm-to-firm competition to a more comprehensive and collaborative form of competition involving entire supply chains (Davis & Spekman, 2004; Gold et al., 2010; Ketchen & Giunipero, 2004; Lambert & Cooper, 2000; Samaranayake, 2005; Solér, Bergström, & Shanahan, 2010).

This new perspective was articulated by Lambert, Cooper, and Pagh (1998), who posited that companies now compete as integrated supply chains, a network of interconnected firms rather than standalone entities. Correspondingly, Towill and Christopher (2002) present the concept of leagility, a supply chain that is both lean and agile, combining the strengths of lean and agile paradigms. Under this new paradigm, a supply chain constitutes a complex network of firms, including suppliers, manufacturers, and distributors. These entities mutually influence and shape each other's performances, thereby creating an interdependent ecosystem (Bigliardi & Bottani, 2010).

Through this lens, SCM can be viewed as an intricate set of processes aimed at optimizing the production and delivery mechanisms of goods, services, and information, extending from suppliers to end consumers (Schiavo, Korzenowski, Soares Batista, Souza, & Scavarda, 2018). Furthermore, SCM's focus has expanded to

include the effectiveness of fulfilling end-user demands, which involves the seamless collaboration and alignment of all parties contributing to the product offering (Cooper, Lambert, & Pagh, 1997). An integral part of this approach is the implementation of agility, adaptability, and alignment among supply chain members. These principles play an instrumental role in determining a firm's competitive performance and ability to respond to market fluctuations (Li, Wu, & Holsapple Clyde, 2015; Towill & Christopher, 2002).

The advent of turbulence in supply chains has led to a new perspective termed *Supply Chain 2.0* (Christopher & Holweg, 2011). This concept recognizes increased instability and market dynamism, calling for more flexible and robust supply chain strategies. The task of managing a supply chain remains a complex undertaking fraught with challenges. The development of a supply strategy demands a deep understanding of various factors, including local market characteristics and the types of inputs utilized. A strategy that overlooks these aspects is bound to falter, leading to a potential business failure (Lee, 2002). Therefore, for firms, the formulation of a supply chain strategy that effectively mitigates risks and safeguards organizational success is of paramount importance (Lee, 2002).

This notion is echoed by Tsiniopoulos and Mena (2015), who proposed that different supply chain configurations are necessary for diverse process structures and product innovations. This suggests a need for dynamic supply chain models that adapt to changing market conditions and evolving product needs. In addition to a suitable strategy, the role of supply chain integration in enhancing performance outcomes cannot be overlooked. The synchronization of processes across supply chain firms is a prerequisite for achieving optimal results (Silvestro & Lustrato, 2014). Successful integration, particularly across operational dimensions, can augment information sharing and streamline decision-making processes. This, in turn, can foster a sustainable competitive advantage and bolster overall business performance (Barratt & Oke, 2007). Through this lens, we see the indispensable role of SCM in today's globalized and interconnected economy.

Sustainability is an increasingly important aspect of operations management (Kleindorfer, Singhal, & Van Wassenhove, 2005), with many companies realizing the importance of environmental, social, and governance (ESG) factors in SCM. Through

this lens, we see the indispensable role of SCM in today's globalized and interconnected economy.

The evolution of SCM has been primarily driven by practitioners, with academic research making significant contributions along the way (Burgess, Singh Prakash, & Koroglu, 2006). Maestrini et al. (2017) classified SCM into eight categories based on the journal's disciplinary area and associated impact factors. These categories are 1) accounting, 2) sector of the study, 3) general management, 4) economics, econometrics, and statistics, 5) sustainability, 6) information management, 7) operations research and management, and 8) operations technology and management.

Despite extensive research on SCM, a notable gap persists in understanding the supply chain of perishable products, particularly food items. Such products possess distinct characteristics, including the need for temperature control and critical lead times, which necessitate a specialized approach to SCM known as food cold chain management (Trienekens, Wognum, Beulens, & van der Vorst, 2012). Recognizing this gap, researchers are increasingly focusing their attention on unraveling the intricacies and specificities of managing the FCC. Their objective is to develop optimized supply chain performance models tailored to the unique needs of perishable products, which have the potential to significantly enhance efficiency and customer satisfaction with this critical sector.

2.2 Research History on the Food Cold Chain

In the last decade, the FCC has attracted the interest of researchers and practitioners with its vital role in satisfying rising global food demand (Ovca & Jevšnik, 2009; Shashi, Singh, & Shabani, 2017). According to Shashi et al. (2020), research on the FCC can be traced to 1995, with a relatively modest number of 80 papers published over the following decade. However, the field witnessed a surge in attention from researchers starting in 2009, leading to exponential growth in research papers by 2013. The significance of this development was underscored when the *International Journal of Logistics Management* dedicated a whole issue to the FCC in 2018.

In 2013, Shukla and Jharkharia (2013) published a literature review on the field of FCCM, called *agri-fresh* SCM (FSCM) in the article. The objective was to address

the major operational issues causing postharvest waste in fresh produce. Their findings revealed that only 86 papers have been published over the last two decades. While most of these studies' main interest was consumer satisfaction and revenue maximization, postharvest waste reduction remained a secondary objective.

Later, Cerchione, Singh, et al. (2018) also conducted a literature review on the field of FCC and categorized it into four areas: 1) factors causing inefficient food cold chain performance, 2) food cold chain sustainability issues, 3) key metrics for food cold chain performance measurement, and 4) major food cold chain performance improvement approaches. Similarly, Shashi et al. (2020) identified four clusters of research themes in the field of FCC using co-citation analysis, which includes 1) the application of radio frequency identification (RFID) technologies, 2) a production and operation planning model, 3) postharvest waste, causes of postharvest wastage, and perishable inventory ordering policies and models, and 4) critical issues in FCC. Despite the different categorization methods, the primary focus of the study on FCCs revolves around the idea of food cold chain performance improvement.

Despite rising interest, there are only a few studies on the cold chain and even fewer on the FCC (Cerchione, Singh, et al., 2018). According to Shashi et al. (2020), approximately 1,100 papers in the field of FCCs were published between 1995 and 2019. Most of these studies were conducted in Western countries, such as the USA (194 articles), the UK (148 articles), Italy (113 articles), and Germany (84 articles). Despite being major food exporters, few countries in Asia actually contribute to the study of the FCC, except China, which published 149 studies. This was also the case in Thailand, even though the country relied heavily on the FCC due to the large amount of perishable food circulating in its logistics system. There are fewer than a hundred studies on the cold chain. Furthermore, studies on FCCs are also scarce, since most existing studies are on PCCs and freezing/refrigerating technology in general.

2.3 Current Research on the Food Cold Chain

According to Shashi et al. (2020), the current body of research on the FCC can be categorized into four research clusters: 1) the application of RFID technologies, 2) the production and operation planning model, 3) postharvest waste, causes of

postharvest wastage, and perishable inventory ordering policies and models, and 4) critical issues in the FCC. This categorization offers a valuable framework for further delving into the breadth and depth of the existing literature on the FCC.

The first cluster revolved around the application of RFID technologies in the FCC. RFID technology is crucial for the FCC because it offers traceability capabilities, temperature management, and shelf-life management. By integrating RFID into the FCC, firms can share real-time information, promoting efficiency and maximizing performance. For instance, Kerry, O'Grady, and Hogan (2006) evaluated RFID technology for its potential use in active and intelligent packaging for meat and related products. Regattieri, Gamberi, and Manzini (2007) also developed an elaborate traceability framework and applied it to the Italian cheese cold chain. Their system was designed using alphanumeric codes and RFID technology, which resulted in a greater level of transparency and accountability within the supply chain. There was also the development of a logistics service model based on a multi-temperature joint distribution system, which provides a competitive advantage for logistics providers in terms of thermal production (Kuo & Chen, 2010). Studies in this cluster also includes challenges that delayed the usage of RFID in the FCC, both economically and technically. Several studies have examined the issue of traceability, which is the primary usage of RFID (Aung & Chang, 2014b; Bosona & Gebresenbet, 2013; Costa et al., 2012; Ringsberg, 2014).

The second research cluster in the FCC is the application of production and operation planning models. Most studies in this cluster revolve around solving food cold chain problems through programming, simulation, optimization, and statistical tools, such as heuristic algorithms, time-windows models, or linear programming (Hsu, Hung, & Li, 2007; Osvald & Stirn, 2008; Rong, Akkerman, & Grunow, 2011). In addition, studies in this cluster explore the use of management and administration tools in solving technical issues. Ahumada and Villalobos (2011a, 2011b) developed food cold chain models, an operational model for short-term planning decisions, and a tactical planning model for production and distribution. These models were developed while considering various factors, including the labor-management cost, preservation value of fresh foods, transportation modes and products' quality for the operational model and price estimation, availability of resources, price dynamics, product decay,

transportation costs, and inventory for the tactical planning model. These models also pioneered a stream of research on the area. Nevertheless, research on this area is still scarce; Soto-Silva, Nadal-Roig, González-Araya, and Pla-Aragones (2016) point out the unavailability of a holistic approach to the design and management of FCCs.

The third cluster of research deals with managing postharvest waste and creating effective inventory ordering policies and models. In the food industry, the reduction of postharvest waste is of the utmost importance. Especially for perishable foods that belong to the cold chain, it is crucial to handle them properly because they can spoil and deteriorate rapidly. When food products are not kept fresh and safe, this issue can lead to severe repercussions for the economy, people's health, and the environment. Therefore, it is imperative to address this issue and prevent adverse effects. Researchers have tackled this problem from various perspectives, turning it into one of the major research topics in the field of FCC. Several works of literature revolve around the topic of preventing and measuring food waste. Parfitt, Barthel, and Macnaughton (2010) conducted a review of the issue of food waste in the global food supply chain, including both food waste within the chain and post-consumer food waste. Their study inspired researchers to explore the issue of food waste from an integrated perspective, including agriculture, food processing, and manufacturing. However, the aforementioned research remains scarce (Papargyropoulou, Lozano, Steinberger, Wright, & bin Ujang, 2014). To minimize food waste, researchers have also extensively studied inventory policies and models. These studies range from ordering policies to pricing policies to transportation policies. For example, Wang and Li (2012) proposed a model that aims to reduce food waste and maximize retailer profit through pricing based on product shelf life.

The final research cluster involved examining issues in the FCC. The research studies belonging to this cluster have a common objective: to identify indicators essential for measuring, evaluating, and monitoring inefficiencies in the chain. Additionally, these studies aim to suggest industry standards and best practices that can be effectively implemented to tackle these issues and improve the overall functioning of the chain. Cai et al. (2010) tackled the freshness-keeping effort between produce and distributors and developed a model that optimized each party's decision. Meanwhile, Aramyan et al. (2007) explored the performance indicators of the FCC as a whole. They

proposed a performance-measurement framework that was tested in the tomato supply chain. Nevertheless, food cold chain performance measurement is more complicated than other types of SC due to its distinguishing features, especially supplying and maintaining temperature levels for products during transport modes (Shabani et al., 2012). According to Shashi et al. (2020), accurate measurement tools can help identify problematic factors and refine forecasts with suitable predictors. Therefore, it is crucial that measurement capabilities be developed to achieve superior performance in the FCC. In addition, exploring the measurement of the FCC leads to another area of research in this cluster, which is its negative impact on the environment, since inefficiency at any point in the FCC can result in food waste, a waste of energy, or the release of harmful toxins.

Unlike the aforementioned categorization, Cerchione, Singh, et al. (2018) categorized the FCC field of study into four clusters, including 1) factors causing inefficient food cold chain performance, 2) food cold chain sustainability issues, 3) key metrics for food cold chain performance measurement, and 4) major food cold chain performance improvement approaches. Interestingly, while the research clusters are different, the research revolves around improving the performance of the FCC through various means. Achieving an efficient FCC is a challenging mission, especially for developing countries, considering that there are several barriers, such as infrastructure, cost, technology, and expertise (Joshi, Banwet, Shankar, & Gandhi, 2012). It is precisely these challenges that underscore the importance of examining food cold chain performance, leading the research topic to be the primary concern of both researchers and practitioners.

2.4 Research on the Food Cold Chain's Performance

Food cold chain performance (FCCP) measures how well the cold chain process preserves the quality of perishable products. Achieving excellent food cold chain performance involves several aspects, such as controlling time and temperature, minimizing waste, being cost effective, and ensuring consumer satisfaction. Superior food cold chain performance provides a competitive edge and benefits for every stakeholder in the chain. A well-managed FCC ensures that products remain fresh and

safe throughout the entire chain, which helps reduce food waste and increase profitability for everyone involved.

2.4.1 Importance of Food Cold Chain Performance and Challenges

According to Shabani et al. (2012), food cold chain performance measurement is more complicated than other types of supply chain-related fields due to its distinguishing features, especially supplying and maintaining temperature levels for a variety of products during disparate transport modes. Furthermore, the FCC's barriers regarding infrastructure, cost, energy, technology, and expertise also hinder firms' efforts to achieve an efficient FCC, especially in developing countries (Joshi et al., 2012). Managing the FCC is a challenging task, even for developed countries with advanced infrastructures (Joshi et al., 2009). Several studies have identified major bottlenecks for efficient FCCs in emerging economies. These bottlenecks include weaker logistics infrastructures, high costs, shortages of refrigerated carriers, a lack of cold storage, improper traceability, inefficient information flow, an absence of integration, and a lack of expertise (Saen, Torabipour, & Shabani, 2011; Kitinoja, 2013; Kuo & Chen, 2010; M & K, 2016; Salin & Nayga, 2003; Shabani et al., 2012; Shukla & Jharkharia, 2013; Zia, 2007). Ashok, Brison, and LeTallec (2017) suggested that insufficient capacity, outdated technology, and inadequate temperature control are obstacles to improving the performance of the FCC. A lack of expertise in the management of the FCC also hinders its performance, since supply chain strategies must align with the characteristics of the product to achieve better performance (Morita, Machuca, Flynn, & Pérez de los Ríos, 2015; Qi, Boyer, & Zhao, 2009). Similarly, Jol et al. (2007) explicitly argued that a lack of expertise in FCCM results in more food waste and foodborne illnesses. A scarcity of resources, including water and energy, is another bottleneck (Joshi et al., 2009). Inefficient temperature control in an FCC can lead to losses of product quality or even microbial hazards, which can affect consumer health (Bogataj et al., 2005; Jol et al., 2007).

2.4.2 Existing Measures and Metrics for Food Cold Chain Performance

Even though there have been many studies on food cold chain performance, there is still limited understanding due to the lack of a proper performance management

framework. Various researchers have emphasized the importance of performance measurement in the FCC. Aramyan et al. (2007) divided performance measurement into four categories: efficiency, flexibility, responsiveness, and food quality. Conversely, Van der Vorst (2000) distinguished the performance indicators of the FCC at three levels: supply chain, organization, and process. At the supply chain level, indicators include product availability, quality, responsiveness, delivery reliability, and total supply-chain costs. At the organizational level, indicators comprise inventory level, throughput time, responsiveness, delivery reliability, and total organizational costs. Finally, the process-level indicators include responsiveness, throughput time, process yield, and process costs. Compared to other supply chain models, the management of food cold chain performance is more complex due to several factors, including the product's perishable nature, short shelf life, number of intermediaries, refrigerated transportation, and storage temperature (Aramyan, Ondersteijn, Kooten, & Oude Lansink, 2006; Joshi et al., 2012). These factors can significantly affect the performance of the cold chain and, therefore, require careful management to ensure the efficient and effective performance of the FCC.

2.4.3 Factors Affecting the Food Cold Chain's Performance

Throughout the decade, researchers have put considerable effort toward compiling factors influencing the performance of FCCs, with the ultimate objective of identifying means to achieve exceptional food cold chain performance (Aiello, La Scalia, & Micale, 2012; Bozorgi, 2016; Fattahi et al., 2013; Joshi et al., 2011; Joshi et al., 2012; Mai et al., 2011; Saif & Elhedhli, 2016; Shabani et al., 2012; Shabani et al., 2015; Sharma & Pai, 2015). Notably, a significant proportion of them could only recognize a few factors at play. For instance, Aiello et al. (2012) introduced a food cold chain performance measurement methodology regarding the expected product quality at a retail store and estimated the expected fraction of perished products according to the FCC's configuration. From another perspective, Shashi et al. (2017) highlighted the significance of integration and collaboration among chain members, as the performance of each member of the chain can significantly impact other members' performance and the FCC. In the same sense, several studies have suggested that collaboration allows the FCC to attain competitiveness in terms of reduced costs, lead time, food waste, and

better product quality, energy efficiency, responsiveness, and customer satisfaction (Balaji & Arshinder, 2016; Beske, Land, & Seuring, 2014; Shashi et al., 2017; Shukla & Jharkharia, 2013). Shabani et al. (2012) developed a benchmarking tool by extending a linear pair model to select the best sales agents, considering that sales agents are essential for FCCM.

To enhance the performance of the FCC, researchers employed a mathematical modeling technique that considered performance factors that were of particular interest to them. Shabani et al. (2015) developed a new procedure to solve the vehicle selection problem in the FCC. Similarly, Farzipoor Saen et al. (2011) proposed a selection model for refrigerated containers by utilizing an innovative data envelopment analysis. Focusing on the meat cold chain, Fattahi et al. (2013) analyzed the chain's characteristics and performance and then developed a performance model. Agustina, Lee, and Piplani (2014) developed vehicle scheduling and routing at a cross-docking center for the FCC.

Given that most existing models fail to provide an accurate measurement of food cold chain performance, Cerchione, Singh, et al. (2018) have proposed a list of sustainable food cold chain performance frameworks that include 25 performance metrics, along with their respective support from the literature. These metrics include carbon emissions reduction, energy consumption reduction, water consumption reduction, food waste reduction, solid waste reduction, reduction in hazardous material use, shelf life, cooling rate, shipping accuracy rate, lead time, green packaging, traceability, product quality and safety, recycling rate, machine breakdown, passive food cold chain rate, temperature monitoring errors, total food cold chain cost, inventory levels, inventory holding days, customer satisfaction, total cost reduction, growth in market share, empty running, and fuel efficiency. Furthermore, they categorized them into five major aspects: infrastructure, integration, stakeholders' interests, value addition, and partners' performance. Similarly, food cold chain performance benchmarking frameworks, key performance factors, and key decision attributes have been proposed to aid in the improvement of the FCC (Joshi et al., 2011; Joshi et al., 2012).

Recently, sustainability practices have become a crucial component of numerous firms' business strategies because these practices can significantly enhance

supply chain performance and provide a distinct competitive advantage (Klassen & Vereecke, 2012; Mincer, 2008; Rao & Holt, 2005). This research trend also extends to the area of the FCC. Researchers have begun to delve into the impact of the FCC on environment and performance. For instance, Bozorgi (2016) stated that the FCC is responsible for nearly 1% of worldwide carbon emissions and suggested an inventory model that considers both costs and carbon emissions to address this issue. Likewise, Meneghetti and Monti (2015) created an optimization model for designing automated, sustainable refrigerated warehouses.

2.5 The Resource-Based View Framework

The resource-based view (RBV) is a pivotal theory in the strategic management literature, offering valuable insights into how firms can attain and sustain a competitive advantage by effectively leveraging their internal resources and capabilities (Eisenhardt & Martin, 2000). This theory emerged during the 1980s as a response to the imperative of understanding why certain firms consistently outperform others in competitive markets (Fahy & Smithee, 1999). At its core, the RBV posits that a firm's resources are the primary drivers of its competitive advantage, enabling it to create value for customers and maintain superior performance over time (Spanos & Lioukas, 2001). RBV concepts can be traced to the works of Chamberlin and Robinson in the 1930s (Fahy & Smithee, 1999). However, it was the substantial contributions of scholars such as Birger Wernerfelt, Richard Rumelt, and Jay Barney in the mid-1980s that elevated the RBV to a prominent position in the field of strategic management (Amit & Schoemaker, 1993; Black & Boal, 1994; Peteraf, 1993; Teece, Pisano, & Shuen, 1997). The work of Wernerfelt in 1984 marked a paradigm shift by reframing the analysis of firms in terms of resources rather than products, with a focus on growth strategies. Subsequent research conducted by Rumelt (1984) on the relationship between strategy and a firm's unique resources and capabilities and Barney (1991) on the connection between a company's resources and its competitive advantage markedly enhanced the comprehension of the RBV, which led to its growing acknowledgment and implementation in the field of strategic management.

Wernerfelt (1984) introduced foundational concepts by proposing that a firm's internal resource base constitutes the primary source of a sustained competitive advantage, diverging from prevailing industry-focused perspectives. His introduction of the VRIN framework delineated the critical attributes of valuable, rare, inimitable, and non-substitutable resources, laying the cornerstone for subsequent investigations into the strategic significance of firm resources. Rumelt (1984) provided empirical support for the RBV by demonstrating a strong correlation between firms possessing distinctive and valuable resources and achieving sustained superior performance, thereby complementing Wernerfelt's theoretical framework. His findings underscored the strategic importance of resource heterogeneity and the role of firm-specific resources in shaping competitive outcomes. Barney (1991) solidified the prominence of the RBV by offering a comprehensive framework for understanding the relationship between firm resources and a sustained competitive advantage. His work expanded on Wernerfelt's VRIN framework, emphasizing the strategic significance of resource heterogeneity, immobility, and durability. Moreover, Barney's conceptualization of firm resources as complex bundles of tangible and intangible assets paved the way for a deeper understanding of the sources of a competitive advantage.

2.5.1 Fundamentals of the Resource-Based View: the VRIN Framework

According to J. Barney (1991), the RBV emphasizes four critical attributes that firm-specific resources must possess to provide a sustained competitive advantage. These attributes are valuable, rare, inimitable, and non-substitutable (VRIN).

The first attribute is that resources must be valuable. Valuable resources enable firms to outperform competitors or mitigate weaknesses by facilitating the implementation of value-creating strategies (Amit & Schoemaker, 1993; Grant, 1991). Such resources can exploit opportunities and neutralize threats from the business environment, contributing important value to customers (Hamel & Prahalad, 1990). Furthermore, valuable resources have the potential to yield superior rates of return and enhance a firm's efficiency and effectiveness (Mahoney & Pandian, 1992).

Second, a firm's resources must be rare, as their scarcity or limited availability makes resources valuable due to their exclusivity (Madhani, 2010). Scarce resources are not equally accessible or distributed among firms, leading to competitive parity

when fewer companies possess the same resources (Rothaermel, 2012). Consequently, firms with relatively high levels of resource rareness can expect to raise their economic rents through resource deployment (Ryman, 1999).

The third attribute is inimitability, which refers to competitors' difficulty replicating valuable resources (Madhani, 2010). If valuable resources are difficult to replicate due to their complexity or acquisition challenges, the competitive advantage of firms that control them can be sustained (Barney, 1991). Protecting valuable resources from imitation is crucial for sustaining a competitive advantage over time, as competitors' inability to replicate strategic resources or assets can contribute to maintaining a firm's superior performance (Peteraf, 1993).

Non-substitutability implies that valuable, rare, and inimitable resources cannot be easily replaced or replicated by similar alternatives. Substitutable resources are not considered a source of a competitive advantage, even if they are valuable, rare, and inimitable (Dierickx & Cool, 1989). The absence of substitutes inhibits competitors' ability to obtain or duplicate strategic resources, leading to the unequal distribution of resources and immobility across competing firms (Oliver, 1997). This differentiation permits firms to generate long-term rents by leveraging resources that are not easily replicable or substitutable, enhancing their competitive position in the market (Talaja, 2012).

The RBV also underscores the importance of the various types of resources that firms possess that contribute to a competitive advantage. Grant (1991) introduced a comprehensive classification of resources, echoed by Maijoor and Witteloostuijn (1996), who defined *resources* as semi-permanent assets encompassing both tangible and intangible elements crucial for firms' sustenance. This classification lays the groundwork for understanding firms' diverse arrays of resources, contributing to their competitive advantages.

Tangible resources constitute the tangible assets and liabilities a firm owns or controls, as posited by Wernerfelt (1984). These assets include financial capital, physical infrastructure, such as factories and equipment, land, and other fixed assets, alongside liquid assets such as stocks of raw materials and bank deposits. Tangible resources, which are quantifiable and easily appraised through conventional accounting methods, hold transparent value and are typically reflected in a firm's balance sheet

(Hall, 1989). However, Grant (1991) highlighted their susceptibility to imitation and substitution by competitors, attributed to their tangible nature.

In contrast, intangible resources encompass a firm's intangible assets, including intellectual property such as trademarks, patents, and copyrights, alongside intangible attributes such as brand reputation, image, product quality, and network associations (Hall, 1992). These intangible resources, often invisible on balance sheets, play a pivotal role in bridging the gap between a firm's balance sheet valuation and its actual market value (Grant, 1991; Rumelt, 1984). Fahy and Smithee (1999) highlighted the resilience of intangible resources against imitability and substitutability, underscoring their strategic significance in conferring a sustained competitive advantage.

Furthermore, researchers have suggested alternative methods for categorizing resources (Amit & Schoemaker, 1993; Barney, 1991; Bogaert, Martens, & Van Cauwenbergh, 1994; Brumagim, 1994; Grant, 1991). Olavarrieta and Ellinger (1997) compiled these classifications and proposed categorizing resources into three main categories: input factors, assets, and capabilities.

Input factors encompass generic resources obtainable from the market that are crucial for a firm's operational activities (Amit & Schoemaker, 1993). Within the supply chain, these factors include tangible elements, such as trucks, warehouse racking, and packaging material, as well as intangible elements, such as personnel skills. When integrated into a firm's operations, these input factors transform into the firm's assets or capabilities, contributing to its overall performance.

Assets represent stocks of available factors owned or controlled by a firm (Amit & Schoemaker, 1993; Dierickx & Cool, 1989). Accumulated over time, assets can be tangible or intangible, yet they share the characteristic of being visible resources (Bogaert et al., 1994). *Tangible assets* include capital equipment, while intangible assets encompass patents, brand names, and codified knowledge (Schulze, 1994). From a supply chain viewpoint, assets range from physical infrastructures, such as warehouses and plants, to technological resources, such as satellite-based communication systems and electronic data interchange (EDI) networks.

Capabilities denote complex combinations of individual skills, assets, and accumulated knowledge exercised through organizational processes (Amit & Schoemaker, 1993; Day, 1994; Schulze, 1994). These capabilities enable firms to

coordinate activities effectively and leverage their resources for a competitive advantage. Some notable supply chain-related capabilities include Wal-Mart's renowned distribution system and Hewlett-Packard's expertise in postponement strategies (Day, 1994; Feitzinger & Lee, 1997; Stalk & Evans-Clark, 1992). Additionally, capabilities extend to teamwork, supplier relationship management, technological prowess, new product development, service delivery, and order fulfillment.

The RBV offers a comprehensive framework for understanding how firms achieve a sustained competitive advantage by strategically using their resources. The framework provides valuable insights into strategic decision making in dynamic environments by emphasizing the attributes of value, rarity, inimitability, and non-substitutability. This theoretical foundation, coupled with practical examples and classifications of resources, enriches our understanding of how firms leverage their internal capabilities to maintain a competitive edge. As organizations navigate the complexities of today's business landscape, the RBV remains a crucial tool for guiding strategic initiatives and enhancing long-term performance.

2.5.2 The Resource-Based View in Supply Chain Management

The RBV has emerged as a pivotal framework for analyzing the relationship between firm-specific resources and supply chain performance. Within the realm of SCM, the framework offers insights into how firms can leverage their internal resources and capabilities to enhance overall supply chain effectiveness and achieve a sustained competitive advantage.

When applied to SCM, the RBV emphasizes the critical role of both tangible and intangible resources in shaping supply chain outcomes. Tangible resources, such as physical infrastructure and technological assets, are instrumental in enabling efficient logistics operations and optimizing supply chain processes (Teece et al., 1997). For instance, investments in advanced warehouse facilities or transportation networks can streamline distribution channels, reduce lead times, and enhance overall supply chain agility. Meanwhile, intangible resources, such as brand reputation, organizational culture, and interfirm relationships, also significantly influence supply chain performance (Lippman & Rumelt, 1982). For example, strong supplier relationships

built on trust and collaboration can lead to greater supply chain integration and coordination. This integration fosters information sharing, joint decision making, and risk pooling, ultimately enhancing supply chain resilience and responsiveness to market changes (Nelson, 1985).

Barney (1991) has recognized logistics capabilities as part of a firm's essential resources, allowing it to execute strategies to enhance its performance. For example, distinctive resources, such as temperature-controlled storage facilities and specialized transportation equipment, are essential for maintaining product quality and safety across the supply chain.

In summary, the application of the RBV in SCM provides a framework for understanding how firms can leverage their internal resources and capabilities to optimize supply chain performance and gain a competitive edge in the marketplace. By focusing on the strategic management of resources within the supply chain context, the RBV offers actionable insights for firms seeking to enhance their supply chain effectiveness and achieve sustainable business success.

Although the RBV highlights the importance of utilizing resources and capabilities to enhance performance in supply chains and gain a competitive advantage, it remains insufficient to develop a performance model specifically for the FCC. While resources and capabilities are necessary, they are not the only factors at play in the field of SCM. Additionally, the framework tends to focus on the perspectives of individual firms, rather than considering the performance of the entire supply chain. While the RBV can help pinpoint the factors that affect food cold chain performance, it can only serve as a foundation. This foundation must be supplemented by insights from other SCM theories and empirical studies to develop a comprehensive and effective performance model for the FCC.

2.6 Structural Equation Modeling

2.6.1 Overview of Structural Equation Modeling

Structural equation modeling (SEM) is a multivariate statistical analysis technique designed to analyze structural relationships. It does not designate a single statistical technique but refers to a family of related procedures. The name *structural*

equation modeling reflects two aspects of the procedure: the structural, or causal, relationships among the variables and the use of equations to represent those relationships. It combines traditional multivariate analysis, such as factor analysis and multiple regression analysis (Kline, 2023). SEM is used to analyze relationships between latent variables that cannot be observed directly as well as their relationship with corresponding observed variables, enabling both confirmatory and exploratory modeling, thus accommodating theory testing and development (Hair, Black, Babin, & Anderson, 2010). The technique is a hypothesis-driven approach that requires a preconceived theory/conceptual model since it confirms the correspondence of the data of the relationships in the conceptual model. According to Pearl (2012), SEM is a causal inference method that takes three inputs and generates three outputs. The inputs include the following:

- 1) A set of qualitative causal hypotheses based on the theory or results of empirical studies is represented in a structural equation model.
- 2) A set of queries about causal relationships among variables of interest.
- 3) Data from experimental or quasi-experimental designs for analysis.

The outputs of SEM include the following:

- 1) Numeric estimates of model parameters for hypothesized effects.
- 2) A set of logical implications of the model.
- 3) The degree to which the testable implications of the model are supported by the data.

Crucially, to utilize SEM efficiently, researchers should have a clear understanding of the following topics: (1) principles of regression techniques, including multiple regression, logistic regression, and probit regression; (2) the correct interpretation of results from tests of statistical significance; and (3) data screening and measure selection (Markus, 2012).

2.6.2 Main Components of SEM

SEM comprises six main components, including latent variables (constructs), manifest variables (indicators), structural relationships, measurement model, structural model, and residuals (**Error! Reference source not found.**).

Latent variables refer to variables that cannot be measured directly but are inferred from other measurable variables. They represent abstract concepts, such as intelligence, satisfaction, or attitudes, which cannot be measured directly. In contrast, *manifest variables* refer to the observed variables used to measure latent variables. They can be directly measured and serve as indicators of underlying latent variables.

The hypothesized causal relationships among latent variables, represented by arrows in the SEM model, are called *structural relationships*. These relationships explain how changes in one latent variable (independent) affect another latent variable (dependent).

The *measurement and structural models* are the two main analytic components of SEM derived from factor analysis and regression analysis. The measurement model, also termed the *outer model*, derived from confirmatory factor analysis, is the part of SEM that specifies and confirms the relationship between latent variables and their corresponding manifest variables. It outlines how the latent variables are measured in terms of the manifested variables. This relationship can be observed through factor loadings, which signify the strength and direction of the relationship. Factor loadings are also used to measure the model's validity, as analysts must ensure that manifest variables only measure their intended latent variables and nothing else. The second part of SEM is the structural model, often called the *inner model*. The structural model illustrates the causal relationship between latent variables, indicating how they affect each other. This process is similar to regression analysis, yet it has the advantage of handling multiple dependent variables and complex relationships. The structural model is the primary focal model of SEM, as each relationship (or path) represents the hypothesis of the tested model. Due to this analysis, these paths are assigned a coefficient similar to that of regression analysis, which indicates the direction and effect variables have on each other.

The final component of SEM is residuals (errors). *Residuals* are discrepancies between the observed and predicted values for the measured variables and structural predictions among the latent variables. They were included in SEM models to account for measurement error and the variation in the variables not explained by the model.

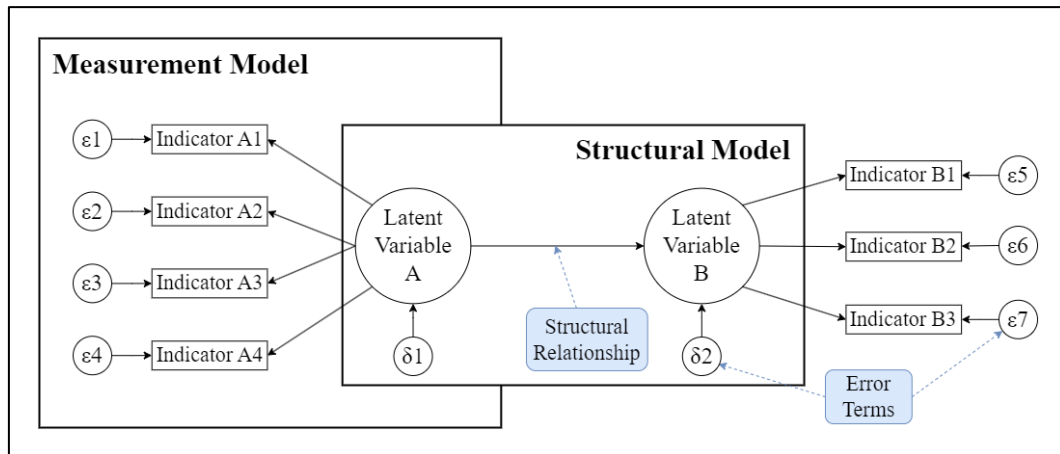


Figure 2.1 Components of SEM

2.6.3 Fundamental Statistics: The Role of Covariance in SEM

The application of covariance as a primary statistical measure in SEM is the cornerstone of this method. Covariance, denoted by cov_{XY} , is a measure of how much two continuously observed variables X and Y vary together, which can be mathematically expressed as follows:

$$cov_{XY} = r_{XY}SD_XSD_Y$$

Here, r_{XY} is the correlation between X and Y, and SD_X and SD_Y are the standard deviations of X and Y, respectively. Covariance allows us to quantify the strength of the linear association between two variables and understand their respective variances. This is crucial in SEM, where the primary objective is to interpret patterns of covariances among a set of observed variables (manifest variables) to explain as much of their variance as possible within the proposed model.

In SEM, the measurement model component utilizes covariance to confirm the relationship between latent variables and their corresponding manifest variables. When a set of observed variables has high covariance, it may indicate that the same latent variable influences them. Meanwhile, covariance also helps determine the relationships between different latent variables in the structural model of SEM. Because these relationships are not directly observable, they are inferred based on the covariance matrix of latent variables. The path coefficients derived from the covariance among the

latent variables describe these relationships. These coefficients ranged from -1 to 1, indicating the strength and direction of the relationship between the two latent variables. Given this understanding, we can then see how these principles of covariance and the role of latent variables lay the groundwork for the complex systems of linear equations that make up SEM.

According to Civelek (2018), SEM consists of a system of linear equations, each reflecting the relationships between manifest and latent variables established through covariance measures. In the context of the measurement model, the relationship between a latent variable (X) and an observed variable (A) could be expressed as follows:

$$A = \lambda_X X + \varepsilon$$

Where λ_X is the factor loading of X on A, and ε represents the error term. Similarly, the structural model relationship between latent variables can be illustrated as follows:

$$X = \beta_X X + \beta_Y Y + \delta$$

Where β_X denotes the coefficients of the paths between latent variable X, indicating the strength and direction of the direct impact that X has on itself. However, β_Y signifies the path coefficients from latent variable Y to X, and δ is an error term. To illustrate this, the linear equations for the model displayed in Figure 2.2 are formulated as follows:

$$Z = \beta_1 X + \beta_2 Y + \delta_1$$

$$W = \beta_3 X + \delta_2$$

$$T = \beta_4 Z + \beta_5 Y + \beta_6 W + \delta_3$$

However, as already mentioned, the structural equation model consists of two parts: the measurement model and the structural model. Hence, there are 15 more regression equations in the measurement model, as shown below:

$$A_1 = \lambda_1 X + \varepsilon_1$$

$$A_2 = \lambda_2 X + \varepsilon_2$$

$$A_3 = \lambda_3 X + \varepsilon_3$$

$$A_4 = \lambda_4 Y + \varepsilon_4$$

$$A_5 = \lambda_5 Y + \varepsilon_5$$

$$A_6 = \lambda_6 Y + \varepsilon_6$$

$$A_7 = \lambda_7 Z + \varepsilon_7$$

$$A_8 = \lambda_8 Z + \varepsilon_8$$

$$A_9 = \lambda_9 Z + \varepsilon_9$$

$$A_{10} = \lambda_{10} W + \varepsilon_{10}$$

$$A_{11} = \lambda_{11} W + \varepsilon_{11}$$

$$A_{12} = \lambda_{12} W + \varepsilon_{12}$$

$$A_{13} = \lambda_{13} T + \varepsilon_{13}$$

$$A_{14} = \lambda_{14} T + \varepsilon_{14}$$

$$A_{15} = \lambda_{15} T + \varepsilon_{15}$$

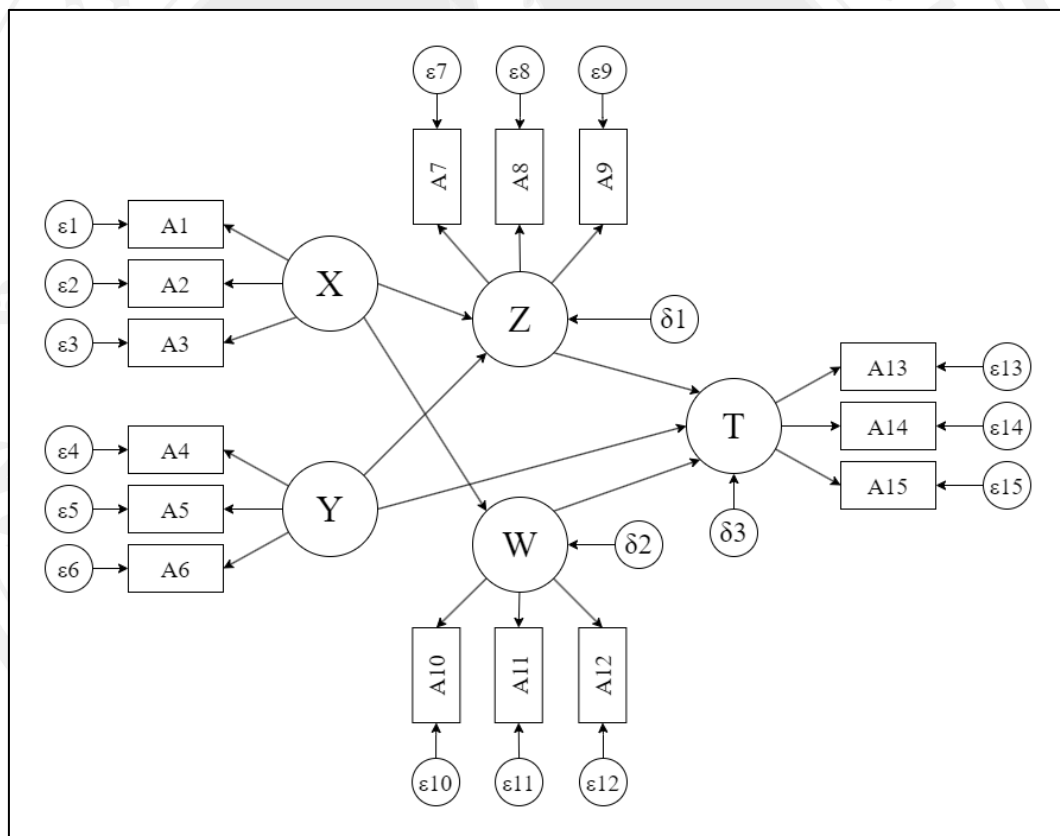


Figure 2.2 Example of SEM

2.6.4 Comparison with Traditional Multivariate Procedures

SEM also provides several advantages over traditional multivariate procedures. One advantage is the ability to explicitly handle measurement errors and missing data, leading to more accurate parameter estimates. It also allows the simultaneous

examination of relationships among variables, allowing more complex models to be tested (Hair et al., 2010). By analyzing relationships simultaneously, SEM offers a lower error rate than regression analysis, where errors can accumulate from multiple analyses. Moreover, latent variables in SEM allow researchers to capture abstract concepts in social science research that are not easily measured directly (Kline, 2023).

2.6.5 Types of SEM: CB–SEM and PLS–SEM

There are two main SEM types: covariance-based SEM (CB–SEM) and partial least squares SEM (PLS–SEM). CB–SEM is based on the covariance matrix of the measured variables and is used to test theories that require the comparison of covariance matrices. The basic assumption of this method is that the data are multivariate normal and that the relationships in the model are linear. As the method focuses on theory testing, CB–SEM is suitable when the research is confirmatory, the model is correctly specified, and the data are normally distributed. According to Hair et al. (2010), CB–SEM requires larger sample sizes and is sensitive to model misspecifications and violations of normality.

Unlike CB–SEM, PLS–SEM is a variance-based approach that focuses on predicting key target constructs and identifying key driver constructs (Hair Jr., Hult, Ringle, & Sarstedt, 2016). It is preferred when the research focus leans toward exploratory or the model is complex with many latent variables and manifested variables, since the method does not require a large sample size (Fornell & Larcker, 1981). Hence, PLS–SEM is particularly suitable when the goal is theory development and the data distribution is non-normal.

The philosophical distinction between CB–SEM and PLS–SEM is straightforward. If the research objective is theory testing and confirmation, then the appropriate method is CB–SEM. In contrast, if the research objective is prediction and theory development, then the appropriate method is PLS–SEM. Conceptually and practically, PLS–SEM is similar to multiple regression analysis. The primary objective is to maximize explained variance in the dependent constructs, but also to evaluate the data quality based on measurement model characteristics. (Hair Jr., Matthews, Matthews, & Sarstedt, 2017).

2.6.6 SEM Process

According to Dash and Paul (2021), the SEM process involves a series of steps, beginning with a clear definition of individual constructs. These constructs, or latent variables, must be represented within a hypothesized model and grounded in structural and measurement theories.

After construct development, the next step is confirmatory factor analysis (CFA). In this step, the measurement model must be specified, and each variable or indicator should be assigned to its respective factors or constructs, leading to the development of a path diagram. Indicator loadings and applicable error terms should also be included to complete the model. The measurement model then undergoes the process of reliability and validity assessment through several indicators, such as Cronbach's alpha and composite reliability (CR). Furthermore, convergent and discriminant validity are evaluated to ascertain the nature of the measurement model and can be assessed through several measures, such as average variance extracted (AVE), outer loadings, the Fornell–Larcker criterion, the Heterotrait–Monotrait Ratio (HTMT), and cross-loadings. Once reliability and validity are ensured, the model is then evaluated for model fit, and modification can be undertaken if required.

The next step is to examine the relationships among the constructs. Structural linkages are established based on relevant theories, followed by an assessment of validity and model fit. All structural relationships are then tested with appropriate statistical tools, particularly regression or path coefficients.

The final stage centers on the findings derived from the model, where conclusions are drawn as per the objectives. Based on these statistical results, suitable recommendations and suggestions are formulated. Hence, from defining individual constructs to drawing conclusions from the model's findings, the SEM process is comprehensive, thorough, and complex, providing in-depth insights into the data analyzed.

2.6.7 Underlying Assumptions of Structural Equation Modeling

Similar to regression analysis, structural equation modeling has its assumptions. According to Civelek (2018), the underlying assumptions of SEM can be summarized as follows:

1) It is assumed that both the observed and latent variables exhibit multivariate normality. That is, the distribution of each type of variable should conform to a multivariate normal distribution.

2) Linearity is another fundamental assumption in SEM. There is an expectation of linear relationships between latent variables, as well as between observed and latent variables.

3) The model assumes the absence of outliers. Outliers can significantly skew the results and affect the reliability of the model.

4) SEM also posits multiple measurements, indicating that each latent variable should be measured by at least three observed variables.

5) The model necessitates no multicollinearity, ensuring that the observed variables are not highly correlated.

6) Last, sample size plays a critical role in SEM. Many of the model's fit indices were influenced by the sample size. It is recommended that the sample size in SEM should be at least 10 times the number of parameters that can be estimated in the model. This requirement ensures a robust and reliable model.

CHAPTER 3

CONCEPTUAL MODEL DEVELOPMENT

This section presents the formulation of the initial conceptual model of food cold chain performance. This model serves the purpose of understanding the pivotal factors influencing the performance of an FCC. This model is designed to solve the existing knowledge gap and provide a complete understanding of the various factors impacting food cold chain performance. Furthermore, it is intended to assist practitioners in the field in optimizing their operations and making informed strategic decisions.

Through a comprehensive literature review, we identified various factors that markedly affect the efficiency of FCCs. These factors have been identified as fundamental constructs of the FCCP model. Once we have identified these constructs, our next step will be to conduct a thorough analysis of their interrelationships and formulate hypotheses to verify these associations.

3.1 Conceptual Model Development

3.1.1 FCC Infrastructure

Several pieces of literature have highlighted that infrastructure plays a vital role in any supply chain, especially the FCC. Facilities and equipment, such as cold storage or refrigerated vehicles, are necessary to maintain the integrity of food along the chain. Studies have shown that weak cold chain infrastructure is the major cause of various inefficiencies in the FCC, such as food waste, poor-quality products, a small processing rate, the high cost of manufacturing, transportation, and cooling, and customer dissatisfaction (James & James, 2010; Joshi et al., 2009; Lal Barediya, Samuel, & Beera, 2013; Rathore, Sharma, & Saxena, 2010; Shabani et al., 2015; Shashi et al., 2017; Zia, 2007). In addition, a sufficient and efficient cold chain infrastructure positively impacts

value addition by extending product life, maintaining quality, and minimizing waste (Aung & Chang, 2014b). Advanced infrastructure technologies have the potential to add value across multiple facets of the FCC (Bosona & Gebresenbet, 2013; Rong et al., 2011). Furthermore, the role of IT infrastructure has been recognized as a significant factor influencing partner performance within FCCs since it enables information exchange and decision support, which help reduce lead times and synchronize logistical processes with consumer demand (van der Vorst, Tromp, & Zee, 2009).

3.1.2 FCC Integration

Several studies have identified supply chain integration, both internal and external, as an essential factor for augmenting supply chain performance, both operational and financial (Chang et al., 2016; Jie et al., 2013; Sharma & Pai, 2015). Effective integration facilitates information sharing, allowing the FCC to respond better to customer needs (Cai et al., 2010; Fabbe-Costes & Jahre, 2008; Koufteros, Vonderembse, & Jayaram, 2005). It also enables resource sharing, which leads to better supply chain performance (Flynn, Huo, & Zhao, 2010; García-Arca, Prado-Prado, & Garrido, 2014). Integration can strengthen decision making, solve inefficiencies in inventory, cost, and waste, and contribute to the enhancement of the value-addition process in the chain.

3.1.3 Sustainability Orientation

In recent decades, researchers and practitioners have been interested in incorporating sustainability practices into supply chain operations and models (Hassini, Surti, & Searcy, 2012). This construct explores the adoption of sustainability initiatives within the cold chain. Sustainable practices encompass a wide range of activities, such as reducing carbon emissions or optimizing inventory. These practices contribute to environmental sustainability and enhance a competitive advantage and, ultimately, the chain's performance (Babagolzadeh et al., 2020). In addition, sustainability practices, such as new green product development, also notably impact a product's value addition. Hsu, Chen, and Chen (2022) confirmed a positive relationship between corporate social responsibility (CSR) and value-added in the supply chain. Sustainability orientation also impacts the performance of supply chain partners. The literature has also

highlighted that firms' sustainable practices can affect other members, leading to better performance for the whole chain (Pagell & Wu, 2009). For instance, reduced costs through waste minimization allow firms and chain members to gain a financial advantage over others.

3.1.4 Value Addition

Value addition is one of the most crucial components of the FCC. Value addition practices significantly contribute to improving chain efficiency, product quality, customer satisfaction, and competitiveness, since they involve anything from improvements in product quality to enhancements in customer service or the reduction of waste. The value-addition process notably influences the quality of the final products, reducing costs and lead times. Various studies have proven that value addition is a crucial factor for a successful business due to its impact on a firm's performance (Aworh, 2015; Martinez, 2014; Shashi et al., 2017).

3.1.5 Partners' Performance

The performance of each member of the FCC directly impacts the chain's overall performance (Ageron, Gunasekaran, & Spalanzani, 2012). According to Cerchione, Singh, et al. (2018), the improved performance of one member of the FCC promotes the performance of others, which ultimately results in superior food cold chain performance. For instance, cost reductions for suppliers could result in minimized final product costs, thus generating value for customers (Aramyan et al., 2007). Likewise, efficient and reliable material delivery and information sharing can streamline operations and ameliorate the chain's performance. Cai et al. (2010) pointed out that delays in material delivery could reduce product quality and increase production lead time, which results in rising total costs and decreasing customer satisfaction.

3.2 Constructs' Interrelationships and Hypotheses' Development

3.2.1 Hypotheses of the Food Cold Chain Infrastructure

Several pieces of literature have highlighted that the infrastructure plays a vital role in any supply chain, especially the FCC. Facilities and equipment, such as cold storage or refrigerated vehicles, are necessary to maintain the integrity of food along the chain. Studies have shown that a weak cold chain infrastructure is the major cause of food waste in the food industry (Rathore et al., 2010). Kitinoja (2013) highlighted that a well-developed food cold chain infrastructure is a prerequisite and must be invested in to maximize chain performance. The availability of refrigerated vehicles, cold warehouses, and distribution centers enables firms to preserve larger volumes and prolong the quality of products, thus reducing waste and boosting their logistics systems (Ashok et al., 2017; Minten, Reardon, Gupta Sunipa, Hu, & Murshid, 2016). In the same sense, Joshi et al. (2009) and Zia (2007) highlighted that the lack of adequate infrastructure is considered a major bottleneck in the FCC and should be addressed to refine the chain's performance. Several works of literature also shared the same viewpoint on the importance of infrastructure on the food cold chain's performance. The lack of an appropriate infrastructure is the main reason for high food wastage, the delivery of a supply of non-value-added products, poor-quality products, a small processing rate, a high cost of manufacturing, transportation, and cooling, and customer dissatisfaction (James & James, 2010; Joshi et al., 2009; Ial Basediya et al., 2013; Shabani et al., 2015; Shashi et al., 2017; Zia, 2007).

Samant et al. (2007) suggested that the adequacy of the cold chain's infrastructure plays a significant role in ensuring the delivery and availability of perishable products. Advanced infrastructure, such as information technology or IoT, also proved beneficial for refining the operation of the FCC and, ultimately, the chain's performance (Balaji & Arshinder, 2016; Milić, Tolić, & Martinović, 2015; Zhan & Tan, 2020). Hence, a well-developed infrastructure can facilitate the processes of food handling, storage, and transportation, thereby improving the efficiency and performance of the cold chain (Bosona & Gebresenbet, 2013).

Infrastructure also significantly impacts the value addition of the FCC. A sufficient and efficient cold chain infrastructure positively impacts value addition by

extending product life, maintaining quality, and minimizing waste (Aung & Chang, 2014b). Advanced infrastructure technologies can also provide value addition in several aspects. For instance, an effective food traceability system adds value in terms of quality assurance and more customer satisfaction (Bosona & Gebresenbet, 2013). Information technology can also facilitate production and distribution planning, thus adding value through improved availability and lower holding costs (Rong et al., 2011). Rediers et al. (2009) also pointed out that the absence of an FCC infrastructure obstructs value-addition efforts, which lead to poor food cold chain performance.

The study also suggested that infrastructure, including governance mechanisms and information systems, can have a significant impact on partner performance in FCCs (van der Vorst et al., 2009). Augmented FCC infrastructure, such as advanced refrigeration and temperature control systems, can enhance the ability of partners to maintain the quality of food products during transportation and storage, thus improving their performance (Bosona & Gebresenbet, 2013). According to Vlajic, van der Vorst, and Haijema (2012), a well-established infrastructure can reduce operational costs in the cold chain, enhancing partners' profitability and performance.

Based on the aforementioned rationale, we formulated hypotheses pertaining to the FCC infrastructure's interconnections with other constructs within the proposed FCCP model.

H1: The FCC's infrastructure affects the FCC's performance.

H2: The FCC's infrastructure affects value addition.

H3: The FCC's infrastructure *affects partners' performance*.

3.2.2 Hypotheses on Food Cold Chain Integration

Food cold chain integration is considered a crucial requirement for achieving superior food cold chain performance. Supply chain integration, both within and between firms, provides a chain with a competitive advantage and improves both operational and financial performance (Chang et al., 2016; Jie et al., 2013; Sharma & Pai, 2015). Ataseven and Nair (2017) highlighted that supply chain integration is crucial for enhancing performance, since customer integration, supplier integration, and internal integration are positively associated with aggregate firm performance, operational performance, and financial performance. While external integration with

suppliers and customers helps foster collaboration and customer responsiveness, internal integration allows firms to synchronize activities efficiently, thereby contributing to better operational performance. The literature has suggested that collaboration among chain members facilitates information sharing, allowing the FCC to understand and respond to customers' needs, leading to heightened performance (Cai et al., 2010; Fabbe-Costes & Jahre, 2008; Koufteros et al., 2005).

According to Aramyan et al. (2007), food cold chain integration can significantly reduce food loss and spoilage, thus increasing the chain's performance. The food cold chain's integration also allows members to share their resources, thereby upgrading the chain's performance. Pels, Pels, and Engelseth (2009) pointed out that information sharing could strengthen decision making and its implementation. Information sharing across the chain also enriched members' decision making and reduced uncertainties (Cao & Zhang, 2011; Pels & Engelseth, 2009). Integrated decision making using shared information also allows firms to allocate their resources efficiently (Zhou & Benton, 2007). In addition, sharing other resources, such as technology, logistics, or packaging, assists FCC members in responding to rising demand by solving the inefficiencies of the inventory, cost, wastage, and lead time (Flynn et al., 2010; García-Arca et al., 2014).

Integration into the FCC also positively influences the value-addition process. Integration helps polish the operating performance and customer satisfaction, which could indirectly lead to better product quality and customer service (Stank, Keller, & Closs, 2001). Similarly, Cagliano et al. (2006) suggested that integration enables the chain to better serve its customers, thereby gaining a customer value advantage. Zhou and Benton (2007) pointed out the benefits of information sharing, which include the creation of business partnerships, heightened business connections, and efficient inventory management. All these benefits ultimately lead to the identification of opportunities for value addition. According to Shashi et al. (2017), the value addition of FCC members can markedly affect that of downstream members. For instance, low-quality raw materials provided by upstream partners will result in poor-quality final products. Through better integration, firms can cooperate seamlessly and assist each other in adding value to the product until it reaches the customer.

Min et al. (2005) also highlighted that joint problem solving and cross-functional, cross-organizational teams can lead to the integration of the supply chain process, which promotes better communication and coordination among partners, thus advancing their performance. Hence, supply chain integration also significantly influences value addition to maximize the value addition of the FCC. According to Richey, Roath, Whipple, and Fawcett (2010), integration can improve the performance of partners by facilitating better coordination and collaboration among members, pooling resources, leveraging complementary skills, and sharing information. Similarly, Fabbe-Costes, Jahre, and Roussat (2009) highlighted the importance of logistics service integration, both internal and external, in streamlining the process among partners and developing the overall performance of the supply chain.

Due to the discussion above, we developed the following hypotheses regarding the connections between food cold chain integration and other constructs in the proposed FCCP model.

H4: FCC integration affects the FCC's performance.

H5: FCC integration affects value addition.

H6: FCC integration affects partners' performance.

3.2.3 Hypotheses on Sustainability Orientation

In recent decades, incorporating sustainability practices into supply chain operations and models has attracted the interest of researchers and practitioners (Hassini et al., 2012). Sustainability is becoming a strategic business initiative as firms realize that sustainable practices can be economical, generate new revenue streams, and increase customer satisfaction (Mincer, 2008). Incorporating sustainability practices into distinct phases of the supply chain leads to an integrated sustainable supply chain, ultimately leading to competitiveness and economic performance (Rao & Holt, 2005). Fraj-Andrés, Martinez-Salinas, and Matute-Vallejo (2009) also confirmed a positive relationship between implementing environmental strategies, such as environmental marketing and orientation, and a firm's operational and commercial performance, leading to better economic performance. The literature indicates that supplier social sustainability adoption not only refines social performance but also contributes to the competitive advantage of the entire supply chain (Klassen & Vereecke, 2012; Rao &

Holt, 2005). Likewise, Mani et al. (2018) suggested a positive relationship between supplier social sustainability practices and supply chain performance. Kleindorfer et al. (2005) also highlighted that sustainability-oriented practices, such as waste reduction, energy conservation, and emission control, can lead to operational efficiencies, which enhance the overall supply chain's performance. In addition, optimizing replenishment policies and transportation schedules can minimize operational and emissions costs (Babagolzadeh et al., 2020). Hence, firms are now enhancing their competitiveness through better sustainability practices.

Studies have shown that sustainability practices affect several aspects of the supply chain, such as new product design, augmented production processes, and other chain activities (Aikenhead et al., 2015; Klewitz & Hansen, 2014). Consequently, these innovative activities ultimately add substantial value to the chain. For instance, sustainable practices, such as waste reduction or energy efficiency, result in lower costs, thus raising the overall value generated for firms (Chkanikova & Mont, 2015). Hsu et al. (2022) confirmed the positive effect of corporate social responsibility (CSR) on the value addition of the supply chain and emphasized the extension of CSR benefits from focal firms to other members of the chain. In addition, Tseng, Lim, and Wong Wai (2015) demonstrated that justifying their rational position in achieving sustainability is crucial for firms in maintaining their reputations, affecting firms' images, and increasing their value.

Several studies have also suggested that a sustainability orientation can positively affect partners' performance. Suppliers' sustainable practices generally positively affect downstream chain members' performance (Hollo, Blome, & Foerstl, 2012). Zhu, Sarkis, and Lai (2013) suggested that institutional pressures can drive the adoption of sustainable SCM practices, leading to the implementation of sustainability practices across the supply chain and, thus, augmenting partners' performance. When shared with partners, the sustainable practices of firms can assist partners with implementing their sustainable strategies, leading to heightened operational efficiency and performance (Vachon & Klassen, 2008). In addition, sustainability-oriented firms usually demand that their partners follow specific environmental standards. According to Beske et al. (2014), firms aiming for sustainable products often impose related

environmental and social criteria on their partners, leading to process improvements, greater efficiency, and enhanced performance.

Based on the preceding discussion, we formulated the following hypotheses reflecting the links between a sustainability orientation and other constructs within the proposed FCCP model.

H7: A sustainability orientation positively affects FCC performance.

H8: A sustainability orientation positively affects value addition.

H9: A sustainability orientation positively affects partners' performance.

3.2.4 Hypothesis on Value Addition

Value addition is crucial for a successful business due to its impact on firm performance (Aworh, 2015; Martinez, 2014; Shashi et al., 2017). Value-addition practices in the supply chain bring several benefits to firms, such as enhanced chain efficiency, better product quality, affordability, availability, higher customer satisfaction, waste minimization, reduced cost, and shorter lead times. Such advantages allow firms to gain a competitive advantage in the marketplace and thereby improve their overall performance (Alonso & Northcote, 2013; Aworh, 2015; Chang et al., 2016; Joshi et al., 2009; Maestre, Poole, & Henson, 2017; Martinez, 2014). Aung and Chang (2014a) suggested that value-addition processes in the FCC, such as better temperature management along the chain, can notably maintain the quality and quantity of food products. Higher quality can result in increased customer satisfaction, leading to repeat purchases and higher sales, ultimately improving the overall food cold chain's performance. Shashi, Tavana, Shabani, and Singh (2019) confirmed a positive relationship between value addition and firm performance and, by extension, food cold chain performance as a whole. In addition, Shashi et al. (2017) explicitly pointed out that the value addition of food cold chain members has a significant influence on that of downstream members of the chain, confirming the significance of the value addition of all members.

Drawing from the above analysis, we constructed the subsequent hypothesis, thereby encapsulating the intricate relationships between value addition and food cold chain performance.

H10: Value addition positively affects FCC performance.

3.2.5 Hypothesis Regarding Partners' Performance

According to Ageron et al. (2012), members' performance is considered an important predictor of overall supply chain performance. The efficient performance of one member of the FCC promotes the performance of others, ultimately resulting in superior performance. For instance, cost reductions at suppliers could result in minimized final product costs, thus generating value for customers, according to Aramyan et al. (2007). Upstream members' better-quality materials and on-time deliveries enable retailers to satisfy customers' expectations (Ageron et al., 2012). Similarly, Cai et al. (2010) noted that delays in material deliveries could reduce product quality and lengthen production lead time, which result in rising total costs and less customer satisfaction. Shashi et al. (2018) empirically confirmed that the performance improvement of each food cold chain member would improve subsequent members' performance. Efficient information sharing is also crucial, as it could improve the decision making, resource utilization, and demand management of other members of the chain (Kuo & Chen, 2010). In addition, collaboration among members, such as information sharing, joint problem solving, and innovation, can enhance their performance individually, leading to the overall performance improvement of the FCC.

According to the above rationale, the following hypothesis was developed to illustrate the relationship between partners' performance and food cold chain performance.

H11: Partners' performance positively affects the FCC's performance.

3.3 Research Model

This model, designed to understand the relationships and dependencies within food cold chain performance (FCCP) is constructed around five key elements: FCC infrastructure, FCC integration, sustainability orientation, value addition, and partners' performance (Figure 3.1). Each element, or construct, represents an aspect of FCCP that can be quantified and studied in relation to the others. Each aspect will be discussed in turn below.

1) FCC Infrastructure: This encompasses the physical and technological facilities, equipment, and systems that support the functioning of the FCC. It includes

cold storage facilities, refrigerated transport systems, inventory management systems, information and communication technologies, and others. This infrastructure is fundamental to the operation of the FCC and is therefore expected to significantly impact food cold chain performance (H1), value addition (H2), and partners' performance (H3).

2) FCC Integration: This reflects the level of coordination, collaboration, and information sharing among the various entities involved in the FCC, such as suppliers, manufacturers, distributors, retailers, and customers. Greater integration can lead to greater efficiency, reduced waste, and better decision making, thereby positively impacting food cold chain performance (H4), value addition (H5), and partners' performance (H6).

3) Sustainability Orientation: This relates to the commitment of food cold chain participants to adopt practices that minimize environmental impacts, optimize resource use, and support long-term sustainability. A strong sustainability orientation can lead to reduced waste, cost savings, and improved public perception, which can enhance food cold chain performance (H7), value addition (H8), and partners' performance (H9).

4) Value Addition: This pertains to the incremental value added to products as they move through the FCC due to factors such as improved product quality, enhanced customer service, and reduced lead times. Higher value addition can contribute to better food cold chain performance (H10).

5) Partners' Performance: This represents the efficiency, effectiveness, and reliability of the various partners involved in the FCC, including suppliers, manufacturers, distributors, and retailers. High-performing partners can enhance the overall performance of the FCC (H11).

The model postulates a series of hypotheses reflecting the interconnections among these elements. This suggests that improvements in food cold chain infrastructure, integration, and sustainability orientation can enhance value addition and partners' performance, ultimately leading to improved FCCP. Conversely, low performance in any of these areas can harm FCCP, illustrating the interdependent nature of the constructs. This model helps illuminate the complex dynamics within FCCP and provides a basis for designing strategies to optimize its performance.

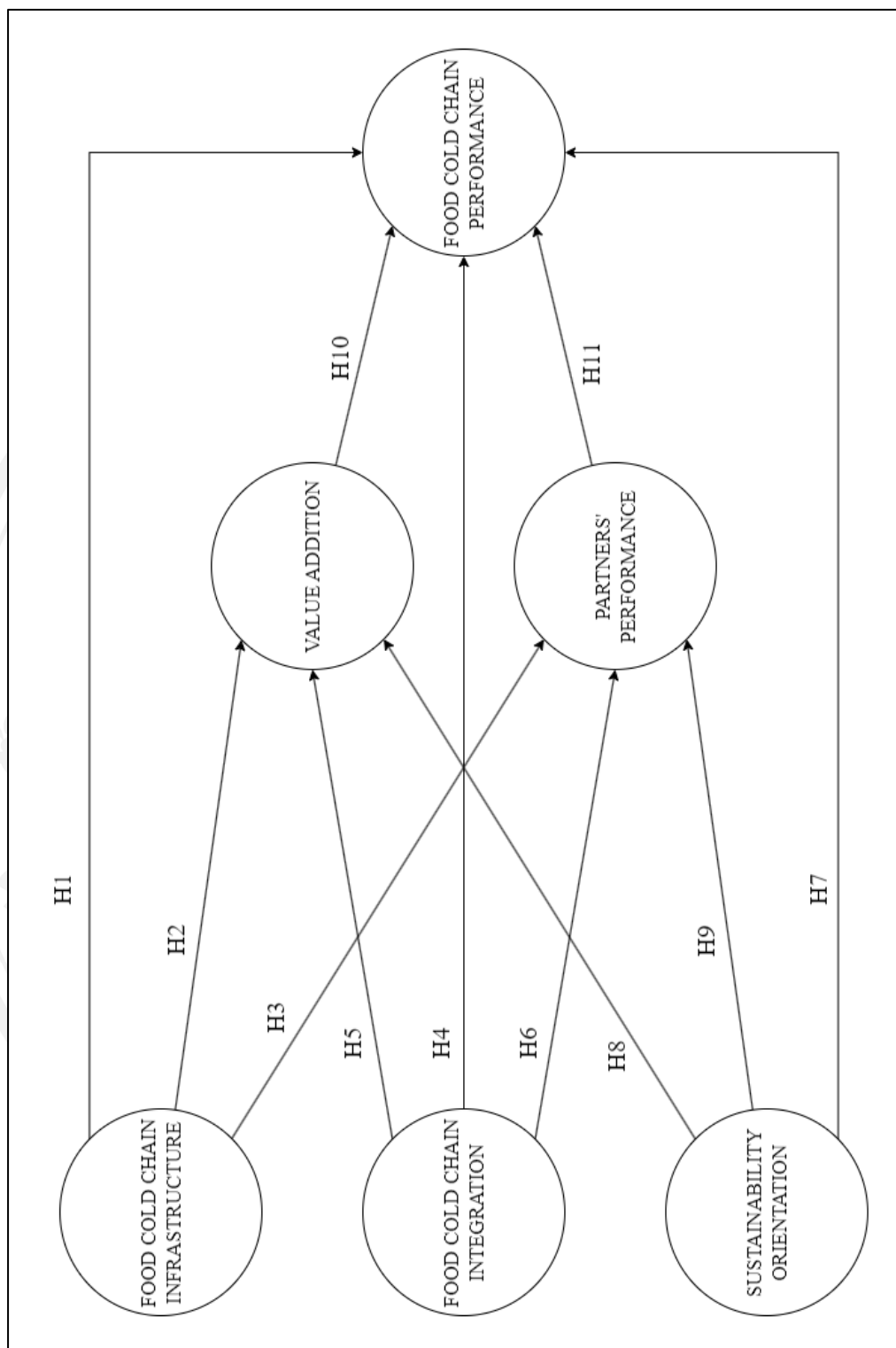


Figure 3.1 The Food Cold Chain Performance Model

3.4 Reconsideration and Exclusion of Stakeholders' Interests

Although stakeholders' interests play a vital role in the FCC due to its influence on other aspects, the inclusion of this construct in the FCCP model raises certain challenges. The FCC involves various stakeholders, including suppliers, manufacturers, employees, third-party logistics providers, distributors, retailers, customers, the government, and financial institutions. The various interests of stakeholders in the FCC, while deemed crucial for its functioning, can cause complications and jeopardize the robustness and interpretability of the model. Even though stakeholder theory posits that effectively managing stakeholders' interests is vital for firms' long-term success, balancing the model's complexity with its explanatory power is crucial. Therefore, instead of including it as a standalone construct, we decided to encapsulate the influence of stakeholder interests through other constructs for the following reasons:

Overlapping with other constructs: The role of stakeholder interests, such as driving improvement, encouraging information sharing, and facilitating sustainability practices, can be captured by other constructs, such as integration or sustainability orientation. This overlap may result in severe multicollinearity and high cross-loading, which poses a significant threat to the discriminant validity of the model. An example of stakeholders' interest in facilitating sustainability practices was demonstrated by Zhu et al. (2013), who suggested that stakeholders' interests could motivate firms to adopt sustainable practices, indirectly leading to enhanced economic performance.

Measurement challenge: Although stakeholders' interests are important, precisely measuring them can be highly challenging. Various stakeholders are involved in the FCC, ranging from suppliers, manufacturers, employees, third-party logistics providers, distributors, retailers, customers, the government, and financial institutions. These stakeholders, while contributing their resources to the focal firms and improving overall performance (Co & Barro, 2009), have diverse interests that are multifaceted and sometimes conflicting (Freeman & Liedtka, 1997). Accurately capturing and quantifying these interests can be difficult and may lead to measurement errors that affect the model's robustness and interpretability.

Complexity of the model: The inclusion of stakeholder interest as a construct significantly increases the complexity of the model. Due to its influence on other

aspects of FCCP, adding stakeholders' interest as a construct potentially raises too many interrelationships among constructs, increasing the model's complications more than its worth. For instance, Vachon and Klassen (2008) highlighted that stakeholder interest is the driving force for collaboration, which helps partners implement sustainable strategies more effectively, leading to improved operational efficiency and performance. Their study provides the rationale for the relationship between stakeholders' interests and three other constructs: direct, indirect, and mediate. While SEM was designed to explore and interpret a complex model, adding a construct should be justified by a substantial increase in explanatory power, which it does not in this case.

Causality issues: While stakeholder interest can impact FCCP, it is possible that successful FCCP could attract more stakeholder interest. For example, Simatupang (2002) proposed that stakeholder interests can encourage better collaboration among partners, leading to better overall performance. In contrast, Eskitürk, Gädeke, and Willing (2015) suggested that supply chain integration can heighten environmental and social performance, improving the company's reputation and reducing risks associated with environmental and social issues, indirectly benefiting stakeholders. This bidirectional relationship can lead to potential endogeneity and reverse causality issues that affect the validity of the results and conclusions drawn from them (Cameron & Trivedi, 2005).

Based on this reasoning, the decision to omit stakeholders' interest as an independent construct from the FCCP model was reached to preserve the model's robustness and interpretability, despite acknowledging its importance. As discussed earlier, certain issues must be considered, including the possibility of overlapping with other constructs, difficulties in accurately measuring the subject, the complexity of the model, and the concern of causality. We understand the complex and multidimensional role stakeholders play in the FCC, often contributing their resources and exerting an influence that can shape overall performance. However, this very complexity, coupled with highly diverse interests, can cloud the clarity and precision required for a constructive model. Instead, we encapsulate stakeholder interests' influence through other constructs, avoiding issues such as multicollinearity, high cross-loading, endogeneity, and reverse causality. This refined approach keeps the focus on the direct,

indirect, and mediated effects of other constructs on FCCP, providing a more straightforward and manageable framework. In this way, we strive to maintain a balance, enabling the FCCP model to offer robust and meaningful insights into the functioning and enhancement of FCCs.



CHAPTER 4

METHODOLOGY

4.1 Research Design and Strategy

4.1.1 Philosophical and Methodological Grounding

The research design in this study is based on a positivist research paradigm, which posits that objective truth can be discovered through systematic and empirical investigations. Positivism upholds the notion that only phenomena that can be observed and measured are considered credible sources of knowledge, thereby endorsing a scientific, objective, and quantifiable approach to research.

Building upon this research paradigm, our study utilizes a quantitative research methodology that is well suited to positivism. This approach emphasizes the importance of measuring and analyzing causal relationships between variables, allowing a comprehensive understanding of the phenomena under investigation. The variables in this study pertaining to the FCCP model are quantitatively measured, and their relationships are empirically tested.

In terms of the methodological approach, this study employs a deductive research strategy in which existing theories and literature about FCCP have been used to form hypotheses regarding causal relationships between the constructs of the FCCP model. Upon the completion of the data collection, empirical methods are subsequently implemented to examine the hypotheses. We rely on partial least squares structural equation modeling (PLS–SEM) as our analytical approach; it is very effective in exploring intricate connections within the FCCP model.

4.1.2 Selection and Justification of PLS–SEM as an Analytical Method

This study employed PLS–SEM for the analysis of the proposed FCCP model due to its suitability and multiple advantages. The following discussion delves into the

rationale behind the chosen methodology, which includes its alignment with our research objective, its advantages, and its proven application in previous studies.

First, PLS–SEM is particularly suitable for exploratory research and theory development. It is a variance-based approach that focuses on predicting key target constructs and identifying key driver constructs (Hair Jr. et al., 2016). According to Dash and Paul (2021), PLS–SEM is preferred for research on prediction and theory development because it aims to maximize explained variances in dependent constructs while evaluating data quality based on measurement model characteristics. Given this research's focus on exploring the relationship between the constructs of the FCCP model, PLS–SEM is considered the most suitable tool. It also aligns well with the objective of maximizing the explained variance of the dependent variables, which is fundamental to our research, in which we aim to explain the performance variance in FCCP. With its focus on prediction and explanatory power, PLS–SEM allowed us to understand how various constructs such as infrastructure, integration, sustainability orientation, value addition, and partner performance interact and contribute to FCCP. It estimates latent variable scores and relationships among constructs while minimizing the residual variances of endogenous constructs, providing a suitable platform for understanding the intricacies of the FCCP model.

Second, it is crucial to understand that PLS–SEM is an ideal method for examining our FCCP model, given its ability to handle complex models and its flexibility with non-normally distributed data. Unlike covariance-based SEM (CB–SEM), PLS–SEM prevails in handling non-normally distributed data that do not meet CB–SEM criteria, with relatively small sample sizes (Dash & Paul, 2021; Hair Jr. et al., 2017). According to Rigdon, Sarstedt, and Ringle (2017), PLS–SEM's flexibility with small sample sizes and its robustness in cases of non-normal data distributions provide a practical advantage over CB–SEM, especially in early-stage research or when large samples are not feasible. Such flexibility proves advantageous considering that the data from the food cold chain stakeholders might not be normally distributed due to their different roles in the chain. PLS–SEM also provides a framework for testing and validating hypothesized relationships in the proposed FCCP model and can simultaneously handle formative and reflective measurement models, offering flexibility in defining and assessing constructs. In addition, PLS–SEM is often the

preferred method for research that prioritizes the prediction and the explanation of variance in dependent variables, which in our case is FCCP due to its orientation toward maximizing explained variance.

Finally, the utilization of PLS–SEM is justified by its proven application in similar research. Numerous studies have employed PLS–SEM to examine the relationship between supply performance and performance factors. For instance, Shashi et al. (2019) utilized the method to examine the relationship between sustainable orientation, supply chain integration, sustainable practice, and environmental and economic performance. Panigrahi, Jena, Meher, and Shrivastava (2023) also employed PLS–SEM to investigate the effect of supply chain agility on operational performance, while considering the mediating effect of cost efficiencies. Similarly, Foo, Lee, Tan, and Ooi (2018) empirically proved that green SCM positively affects sustainability performance through PLS–SEM and artificial neural network analysis.

Although PLS–SEM is the most suitable tool chosen for this research, it is important to acknowledge other methods that could be applicable in analyzing our proposed model.

The first possible methodological tool is covariance-based SEM (CB–SEM), which is a direct alternative to PLS–SEM. It is known for its statistical robustness and superior control for Type I errors. However, CB–SEM requires more rigorous assumptions, such as normality and large sample sizes. Another SEM approach is Bayesian SEM, which offers flexibility and the ability to incorporate prior knowledge. Nevertheless, it requires a higher level of statistical expertise and can be more computationally intensive. Considering the exploratory nature of this study and the model's complexity, PLS–SEM is preferable; it focuses on prediction and its ability to handle complex models without strict assumptions or substantial computational. Generalized structured component analysis (GSCA) is another component-based path modeling approach similar to PLS–SEM, differing mainly in how it handles measurement errors and component scores. However, due to limited flexibility in handling both formative and reflective measurement models and their stricter requirements for model specification, this method is less suitable for the complex and exploratory nature of this research. There is also the general linear model (GLM), which

is the more traditional statistical method, yet it is more suitable for less complex models and more straightforward hypotheses.

4.2 Data Collection

4.2.1 Sample Population and Sampling Method

This study investigated food cold chain stakeholders operating in Thailand. The primary sample population comprised various stakeholders, including suppliers, manufacturers, distributors, retailers, and third-party logistics providers. To conduct a thorough examination of the varied and extensive demographics, a stratified random sampling methodology was implemented. This approach ensured that individuals from diverse segments of the FCC, situated in different regions within Thailand and operating at varying scales, were adequately represented.

4.2.2 Survey Instrument Design and Deployment

The survey instrument was meticulously developed based on the FCCCP model, as detailed in Chapter 3. The questionnaire was formulated based on the constructs and relationships identified from the literature review and the conceptual FCCCP model. To ensure relevance to the unique context of the FCC in Thailand, we adapted items for each construct from previous studies and tailored them accordingly. In this study, the items were assessed using a 5-point Likert scale, which was chosen because of its simplicity, efficiency, and proven effectiveness in social science research.

To enhance the efficacy of the survey tool and guarantee its precision, we sought counsel from scholarly authorities in SCM and seasoned professionals in the FCC sector. Their invaluable insights added another layer of face validity to the instrument and assisted in making the questionnaire more relevant and comprehensible. The final version of the survey was designed to be succinct to maintain participant engagement, typically taking about 15–20 minutes to complete.

4.2.3 Data Collection Procedure and Timeline

From April to June 2023, a comprehensive data collection process was implemented through a web-based platform. The initial phase of the data collection

process involved sending invitations to the participants, which were followed up by regular reminders to increase the response rate. The data collection platform saved and monitored the responses, guaranteeing the utmost confidentiality and security of the data provided by the participants.

At the end of the three-month data collection period, all data were exported for preliminary cleaning and screening. This involved an extensive examination of the data to check for any missing information, outliers, or inconsistencies that could negatively impact the analysis. The screening process was meticulously conducted to ensure that only valid and reliable data were selected for the subsequent analytic phase. Overall, this comprehensive data collection and screening process was designed to ensure the accuracy and validity of the results obtained from the study.

4.3 Measurement of Variables

Measures for the variables of the FCCP model were derived from a comprehensive review of related literature and expert opinions. These measures serve as observed variables (indicators) of the latent constructs in the model. In the sections that follow, a detailed explanation is provided of how each variable is measured. A comprehensive table encompassing all indicators, along with their respective descriptions, is provided at the end of this section (Table 4.1).

4.3.1 Measurement of Food Cold Chain Infrastructure

The infrastructure of the FCC plays a critical role in the chain's performance. To accurately assess the state of the FCC's infrastructure, we identified four key indicators that have been established through expert insights and research (Al-Shboul, 2017; McCarthy-Byrne & Mentzer, 2011). The first, transportation infrastructure, consolidates the use of various modes, such as roads, railways, air travel, and seaports, in delivering products. The second indicator, communication infrastructure, gauges the reliability of telecommunication and electronic communication systems and the ability to access product information electronically. The third, personnel and knowledge infrastructure, measures the commitment to personnel training, regular team meetings, and understanding performance evaluations, indicating the human capital and

knowledge management practices. Last, cold chain facilities, introduced explicitly in the context of FCCs, assess the availability, efficiency, and reliability of the facilities and equipment used to manage temperature-sensitive food products.

4.3.2 Measurement of Food Cold Chain Integration

Following the development of FCC infrastructure measures, we now proceed to explore measurements for FCC integration. In the context of any supply chain, the measurement of integration is divided into internal and external. *Internal integration* refers to the harmonization of activities within an organization to ensure smooth operation. However, *external integration* refers to the cooperation and coordination of actions between a company and its external partners, such as suppliers and customers. Our measurement indicators were derived from a variety of previous studies (Abdallah, Rawadiah, Al-Byati, & Alhyari, 2021; Basnet, 2013; Cerchione, Centobelli, & Shabani, 2018; Shashi et al., 2019). These indicators were then refined with expert insights to ensure they were tailored to the context of the FCC.

The measures for internal integration include elements such as interdepartmental interactive cooperation, responsiveness, synchronized activities, shared visions and objectives, regular interaction and information exchange, joint planning for supply chain issues, and accessible departments and cross-functional teams. For external integration, measurement indicators include collaborative planning and problem solving with suppliers, the implementation of an efficient ordering system, the involvement of suppliers in product development, open communication, and information sharing with partners, and regular contact and involvement with customers in product design. Three additional measures were proposed based on expert opinion: collaboration with regulators, temperature monitoring with partners, and supplier compliance with food safety regulations. Collaboration with regulators leads to a shared understanding and the ability to adapt operations in response to changing regulations. Temperature monitoring is important to ensure the integrity of the cold chain, while supplier compliance ensures that the safety of food products is maintained throughout the entire supply chain.

4.3.3 Measurement of Sustainability Orientation

Sustainability orientation is one of the exogenous constructs in the FCCP model that emphasizes the role of businesses in promoting sustainability and managing environmental challenges, particularly those within the FCC. The development of measurement for this construct is derived from two primary studies: Kuckertz and Wagner (2010) and Roxas and Coetzer (2012). The result is a comprehensive set of eight indicators that can effectively measure sustainability orientation in the FCC. These indicators cover aspects from the environmental role of businesses to their commitment to environmental protection.

The indicator selection process was primarily driven by the scale created by Kuckertz and Wagner (2010) because their work is widely recognized and applied in much research in this area. A total of five indicators were derived from their scale, which included the following: 1) businesses' environmental role, 2) sustainability advantages, 3) corporate social responsibility, 4) environmental challenges, and 5) increased responsibility. Additionally, the scales proposed by Roxas and Coetzer (2012) were incorporated, resulting in the inclusion of three more indicators: 6) environmental knowledge, 7) sustainability integration, and 8) commitment to protection.

4.3.4 Measurement of Value Addition

The value-addition construct of the FCCP model is measured using a set of indicators derived from the literature, including Shashi et al. (2017) and Shashi et al. (2019). In addition, recognizing the unique nature of the FCC, we refined these indicators based on expert opinions to ensure an accurate and context-specific reflection of value addition in this sphere. The selected indicators measure a spectrum of value-adding factors, such as quality improvement, effective sorting and grading, appealing packaging design, demand satisfaction, innovative processing, and strategic marketing. Each of these aspects contributes uniquely to the overall value addition of the FCC and is critical for enhancing the performance of the FCCP model.

4.3.5 Measurement of Partners' Performance

The measurement of partners' performance construct was meticulously articulated using insights from research (Abdallah et al., 2021; Al-Shboul, 2017). An emphasis was placed on five core indicators. First, market influence was developed to capture the firm's and customers' market share and sales influence. Financial performance was deemed critical, focusing on the firm's and customers' return on sales and investment. The cost efficiency indicator considers the reduction of the total product cost to the final customer, marking an essential aspect of partners' performance. Inventory efficiency was constructed to reflect the efficiency of inventory turnover. Last, product customization and flexibility was included to measure a firm's ability to increase product customization and flexibility. These indicators are expected to provide an accurate, comprehensive reflection of the partners' performance in the FCCP model.

4.3.6 Measurement of the Food Cold Chain's Performance

The FCCP measurement was devised using an extensive review of the related literature, including Aramyan et al. (2007) and Fattahi et al. (2013). This construct contains six key indicators that succinctly capture the intricacies of FCCP. *Cost efficiency* denotes elements such as production, distribution, and transaction costs. *Profitability indicators* reflect profit, turnover, and return on investment. *Inventory management* covers aspects related to warehousing, storage, and loss control. The *service quality indicator* captures elements such as customer satisfaction, volume flexibility, and delivery flexibility. *Operational efficiency* reflects the firm's ability to meet customer demands, including customer response time and lead time. Finally, *product and process quality* targets aspects such as product safety, process quality, and environmental considerations. The development of these indicators is expected to provide a holistic representation of FCCP.

Table 4.1 List of Measures

Construct	Index	Indicator Name	Description
Food Cold Chain Infrastructure	INF1	Transportation Infrastructure	This measures the efficiency and breadth of the transportation methods used, such as roads, railways, air travel, and seaports, for product delivery.
	INF2	Communication Infrastructure	This evaluates the reliability and extent of using information technology for communication and accessing product information.
	INF3	Personnel and Knowledge Infrastructure	This assesses the level of commitment to staff training, collaborations, and the understanding of performance evaluations.
	INF4	Cold Chain Facilities	This measures the availability, efficiency, dependability, and importance of facilities and equipment managing temperature-sensitive food products.
Food Cold Chain Integration	IN1	Interdepartmental Interactive Cooperation	This assesses the level of interactive cooperation and conflict resolution across departments.
	IN2	Responsiveness and Synchronized Activities	This measures the organization's ability to respond to departmental needs and coordinate activities across departments.
	IN3	Shared Vision and Objectives	This indicator evaluates the presence of a common vision and joint objectives across the company.
	IN4	Regular Interaction and Information Exchange	This assesses the frequency and effectiveness of interactions and information exchanges.

Construct	Index	Indicator Name	Description
	IN5	Joint Planning for Supply Chain Issues	This measures the extent of collaborative planning to predict and solve supply chain issues.
	IN6	Accessible Departments and Cross-Functional Teams	This evaluates the accessibility of departments and the frequency of cross-departmental collaborations.
	IN7	Collaboration with Regulators	This measures the organization's efficiency in working with regulatory bodies or complying with industry standards.
	IN8	Collaborative Planning and Problem Solving with Suppliers	This measures the level of cooperative planning and joint problem-solving sessions with suppliers.
	IN9	Efficient Ordering System with Suppliers	This evaluates the speed and efficiency of the ordering system with suppliers.
	IN10	Involvement of Suppliers in Product Development	This measures the extent of key supplier involvement in new product development processes.
	IN11	Open Communication and Information Sharing with Partners	This assesses the level of open communication and data sharing, including production planning and demand forecast data, with partners.
	IN12	Regular Contact and Involvement of Customers in Product Design	This measures the frequency of contact with customers and their involvement in the product design process.

Construct	Index	Indicator Name	Description
Sustainability Orientation	IN13	Temperature Monitoring with Partners	This assesses the extent of temperature data sharing with partners to maintain the integrity of the cold chain.
	IN14	Supplier Compliance with Food Safety Regulations	This measures how the organization ensures that its suppliers adhere to relevant food safety regulations.
	SO1	Businesses' Environmental Role	This assesses the perceived importance of businesses in protecting the environment.
	SO2	Sustainability Advantage	This evaluates the recognition of the benefits that sustainability brings in attracting and retaining qualified staff.
	SO3	Corporate Social Responsibility	This gauges the belief that corporate social responsibility should be a fundamental part of all company operations.
	SO4	Environmental Challenges	This measures the understanding and acknowledgment of environmental issues as significant societal challenges.
	SO5	Increased Responsibility	This reflects the opinion that businesses should bear a larger share of social responsibility.
	SO6	Environmental Knowledge	This evaluates the level of knowledge and awareness concerning environmental protection and related issues.
	SO7	Sustainability Integration	This gauges the integration of sustainable practices into business plans and operations.

Construct	Index	Indicator Name	Description
	SO8	Commitment to Protection	This measures the firm's commitment to environmental protection as part of its business operations.
Value Addition	VA1	Quality Improvement	This indicator measures the extent to which cold chain processes boost the quality of food products.
	VA2	Effective Sorting and Grading	This measures the efficacy of sorting and grading processes based on product characteristics and quality attributes.
	VA3	Packaging Appeal	This assesses the visual appeal and informativeness of the packaging design.
	VA4	Demand Satisfaction	This indicator gauges how much the quantity of products (normal and value added) effectively meets market demand.
	VA5	Innovative Processing	This measures the utilization of innovative processing methods to enhance product quality and appeal.
	VA6	Strategic Marketing	This gauges the effectiveness of retail displays, strategic retail locations, promotional activities, and product availability in driving sales of cold chain products.
Partners' Performance	PP1	Market Influence	This evaluates partners' market share and sales performance.

Construct	Index	Indicator Name	Description
Food Cold Chain Performance	PP2	Financial Performance	This measures factors related to partners' returns on sales and investments.
	PP3	Cost Efficiency of Partners	This assesses how well partners reduce the total product cost.
	PP4	Inventory Efficiency of Partners	This gauges how efficiently partners manage their inventory turnover.
	PP5	Product Customization and Flexibility	This measures partners' ability to request and handle product customization and flexibility.
	FCP1	Cost Efficiency	This covers everything related to the costs of production, distribution, and transactions.
	FCP2	Profitability	This evaluates factors tied to profit, turnover, and return on investment.
	FCP3	Inventory Management	This indicator assesses aspects of inventory ranging from warehousing to damage and loss.
	FCP4	Customer Satisfaction	This measures customer satisfaction throughout the transaction process.
	FCP5	Flexibility	This includes aspects related to volume and delivery flexibility.
	FCP6	Order Handling	This covers management aspects of back orders and lost sales.
	FCP7	Product Quality	This pertains to attributes such as sensory properties, shelf life, and appearance.

Construct	Index	Indicator Name	Description
	FCP8	Product Safety and Health	This relates to aspects such as product hygiene and safety.
	FCP9	Product Reliability	This evaluates factors such as product reliability and convenience.
	FCP10	Process Quality	This involves characteristics of the production system and traceability.
	FCP11	Environmental Impact	This encompasses aspects tied to energy use, water use, and recycling.
	FCP12	Marketing	This evaluates factors related to promotional activities and customer service.

4.4 Implementation of PLS–SEM

This research utilized the partial least squares structural equation modeling (PLS–SEM) technique to examine the collected data. This approach involved two primary steps: 1) model specification and 2) estimation and assessment. The analysis was conducted using SmartPLS 4.0 software, which is renowned for its robust computation capabilities and user-friendly interface.

4.4.1 Model Specification

The specification of the FCCP model in SmartPLS involves identifying the constructs and relationships based on the literature. While the paths between constructs represented hypothesized relationships, there were two types of constructs, including reflective and formative, which were assigned based on the nature of each construct. In reflective constructs, also termed *effect indicators*, changes in the latent variable induce alterations in its indicators, which are interchangeable and represent different manifestations of the same underlying construct. As such, these indicators are expected to be correlated, reflecting the same construct, and the omission of an indicator does not alter the conceptual domain of the construct. Here, the latent variable is the cause, and the indicators are the effects. In contrast, formative constructs, or causal indicators, operate inversely. In this framework, changes in the indicators prompt changes in the latent variable. These indicators are unique, non-interchangeable contributors to the latent variable, and their lack of necessary correlation is due to each potentially contributing independently to the construct. Omitting an indicator in this scenario can shift the conceptual domain of the construct, signifying that in formative constructs, the indicators are the cause, and the latent variable is the effect. The evaluation of formative constructs demands distinct criteria, including content validity, multicollinearity, and the significance and relevance of indicator weights.

The FCC infrastructure construct is reflective, as components including transportation infrastructure, communication infrastructure, personnel and knowledge infrastructure, and cold chain facilities are considered reflections of the overall quality and state of the FCC infrastructure. Enhancements in FCC infrastructure are expected to lead to improvements in each of these specific aspects. The FCC integration construct

is also reflective, depicted through indicators ranging from interdepartmental interactive cooperation to supplier compliance to food safety regulations. More overall integration is expected to result in improvements in each indicator. A sustainability orientation is deemed reflective, with indicators such as businesses' environmental role, sustainability advantage, and corporate social responsibility expected to move in tandem with the firm's overall orientation toward sustainability. The value-addition construct, inclusive of indicators such as quality improvement, effective sorting and grading, and packaging appeal, is considered reflective, as an increase in overall value addition is expected to correspond with improvements in these indicators. The partners' performance construct is reflective, with indicators such as market influence, financial performance, and the cost efficiency of partners acting as mirrors to the overall performance of partners. Better partner performance is expected to result in enhancements in these indicators. Finally, the FCCP construct is treated as reflective, with indicators such as cost efficiency, profitability, and inventory management representing outcomes or reflections of the overall FCCP. It is posited that an improvement in FCCP will be associated with improvements in each of these indicators. In these constructs, the indicators are viewed as manifestations or reflections of the latent constructs, suggesting that changes in the construct are expected to result in corresponding changes to all its indicators.

4.4.2 Model Estimation and Assessment

After specifying the model, the PLS path model was estimated by running the PLS algorithm, which provided the path coefficients and helped determine the strength and direction of the relationships between the constructs. Subsequently, a bootstrapping procedure with 5,000 subsamples was run to generate the standard errors and t-values necessary for hypothesis testing.

In PLS-SEM, the path coefficients are akin to the standardized beta coefficients in multiple regression analysis. These coefficients help to explain how much the dependent variable is expected to change per unit change in the independent variable, assuming that other variables are constant. A higher absolute value of a path coefficient signifies a stronger relationship, and the sign of the coefficient (positive or negative) indicates the direction of the relationship.

The assessment stage involves two primary assessments: the measurement model and the structural model. The measurement model assessment targets the reliability and validity of the model. The reliability of the model can be ensured by examining factor loadings, Cronbach's alpha, and composite reliability (CR). The model's validity can be assessed in terms of convergent validity, through average variance extracted (AVE) and discriminant validity, using cross-loadings and other methods such as the Fornell–Larcker criterion or heterotrait–monotrait ratio (HTMT). In addition, the variance inflation factor (VIF) was used to check for collinearity among the indicators for the formative models.

The structural model assessment evaluates the explained variance (R-square) and the significance of the path coefficients. R-squared values represent the proportion of variance in dependent variables (endogenous constructs) that can be explained by independent variables (exogenous constructs). Through a bootstrapping procedure with 5,000 subsamples, the significance of path coefficients was measured through T-statistics. This process also allowed us to assess the outer loadings for the statistical significance of the indicators.

In addition, we considered model-fit measures to evaluate the overall performance and validity of the model. Specifically, the standardized root mean square residual (SRMR) and the normed fit index (NFI) were employed as measures of the overall model fit, evaluating how well our proposed model fit the collected data.

4.5 Data Analysis and Interpretation

In analyzing the results derived from PLS–SEM, it is crucial to focus on key statistical indicators. Each of these statistics provides unique insights and serves a specific purpose in contributing to a comprehensive understanding of the research findings. The following are key statistical measures and their interpretations.

4.5.1 Validity and Reliability Measures

The reliability of our model can be examined through several measures. For reflective constructs, Cronbach's alpha and composite reliability (CR) are conventional, examining the consistency of the indicator, in which values closer to 1

indicate higher construct reliability. The literature suggests that all constructs' Cronbach's alpha and composite reliability should reach the threshold of 0.7 and 0.6, respectively (Bagozzi & Yi, 1988; Nunnally, 1994).

Validity is another critical aspect of PLS–SEM, including both convergent validity and discriminant validity. We can appraise the convergent validity of constructs through average variance extracted (AVE) and outer loadings. An AVE value of 0.5 or more indicates acceptable convergent validity. For outer loadings, Stevens (2012) suggested that there should be no indicators with loadings lower than 0.7 to ensure the model's validity. Discriminant validity can be examined through the Fornell–Larcker criterion, HTMT ratio, or cross-loadings. According to Fornell and Larcker (1981), to satisfy discriminant validity, the square root of the AVE of each construct should be higher than the correlations involving the construct. However, the HTMT ratio is a more stringent criterion for discriminant validity. Henseler, Ringle, and Sarstedt (2015) recommended a threshold of 0.85, meaning that an HTMT value less than 0.85 generally indicates sufficient discriminant validity, although in more conservative settings, a threshold of 0.90 may be used. In assessing cross-loading, researchers suggest that the primary loading of an indicator on its assigned construct should be significantly higher than its cross-loadings with other constructs. A common guideline is that the disparity should be at least 0.1. Furthermore, the variance inflation factor (VIF) can be used to identify and mitigate potential multicollinearity issues among the indicators of the construct, contributing to the construct's discriminant validity. In general, VIFs greater than 10 signal severe multicollinearity problems (Mason & Perreault Jr., 1991).

4.5.2 Interpreting the Structural Model

Interpreting the structural model in PLS–SEM requires a comprehensive understanding of the significance of path coefficients, the explanation of variance within the constructs, and a thorough examination of effect sizes. The significance of these path coefficients was assessed using t-statistics, which were generated through a bootstrapping procedure. Statistically significant coefficients lend support to the hypothesized relationships outlined in the model. The R-squared value in the structural model acts as a crucial indicator, revealing the proportion of total variance in the

endogenous constructs that is accounted for by their corresponding exogenous constructs.

Path coefficients are key elements of the PLS–SEM result. It represents the relationship between constructs in terms of both direction and strength. Path coefficients range from -1 to 1, where a positive number indicates a positive relationship between the constructs, and an increase in one leads to an increase in the other. In contrast, a negative coefficient implies an inverse relationship. In simple terms, path coefficients convey how much a dependent variable is expected to change for each one-unit change in the independent variable, assuming that all other variables are held constant. The strength of the relationship can be observed through the absolute value of the path coefficient. A coefficient closer to -1 or 1 indicates a strong relationship, while 0 suggests a weak or no relationship. Moreover, the significance of the path coefficient should be confirmed through a bootstrapping procedure to discern whether the observed relationship is statistically significant.

Effect sizes (f^2) reflect the magnitude of the relationship between two constructs, indicating the size of the impact that each construct has on another. This metric is used to determine the substantive significance of a path coefficient. The larger the effect size, the more meaningful or substantial the relationship. The interpretation of effect sizes follows Cohen's guidelines: small effect ($f^2 = 0.02$), medium effect ($f^2 = 0.15$), and large effect ($f^2 = 0.35$). An effect size of 0 suggests that the predictor has no effect on the dependent variable, regardless of whether the effect is statistically significant.

R-squared values offer a measure of how much variance in dependent variables can be explained by the independent variables in the model. These values, ranging between 0 and 1, are interpreted as the percentage of the variance in the endogenous construct explained by all its exogenous constructs in the model. A higher R-squared value indicates better explanatory power for the independent variables. According to Falk and Miller (1992), the baseline threshold for R-squared is 0.1, which suggests that the model explains at least 10% of the variance in the dependent variable to be considered meaningful.

4.5.3 Considering Model Fit and Goodness-of-Fit Measures

Two common measures, the Standardized Root Mean Square Residual (SRMR) and the Normed Fit Index (NFI), were used to evaluate the overall model's performance. The SRMR is a measure of the difference between the observed correlation matrix and the model's predicted correlation matrix, meaning that the lower SRMR indicates that the residuals between the observed data and the model's predictions are small on average. Conversely, the NFI is a comparative fit index that compares the chi-square value of the model to the chi-square value of a null model. Higher values indicate that the model is a better fit than the null model. Together, these indicators illuminate how well the hypothesized model fits the collected data. According to Hu and Bentler (1999), an SRMR value of less than 0.08 and an NFI value greater than 0.90 indicate a well-fitting model, demonstrating satisfactory alignment between the proposed model and the collected data.

4.6 Ethical Considerations

Since this research involved human participants, several ethical considerations were considered during the data collection and analysis. First, all respondents were informed about the purpose and procedures of the study, including how their data would be used and stored before they participated in the survey. Subjects were also assured that participation was entirely voluntary and that they could withdraw at any time without any consequences.

The privacy and confidentiality of the informants was maintained throughout the research. All personal data are anonymous and securely stored. In addition, the data collected were solely used for this research and were not shared with third parties. All the subjects' responses were treated confidentially and presented in an aggregated manner in the findings to prevent individual identification. Access to their data was restricted solely to the researcher. In line with good practice in research ethics and data protection, the research data will be stored for five years following the completion of this project. They will be permanently deleted to further safeguard the privacy of the participants.

Regarding data integrity, the researcher upheld the principles of honesty and transparency. All procedures followed accepted social science research standards, with no data fabrication or falsification. Any potential conflicts of interest were declared up front to prevent biased results.

4.7 Limitations and Assumptions

While this study provides valuable insights into the factors affecting Thailand's food cold chain performance, it is not without limitations. The first limitation relates to the scope and generalizability of the findings. As the sample is restricted to firms in Thailand's food cold chain industry, the findings may not accurately apply to other countries or cultural contexts. Second, the study's cross-sectional nature provides only a snapshot of the information at one point in time and does not capture changes over time.

This study assumes that subjects have provided honest and accurate responses to the survey questions. However, there is always the potential for social desirability bias, in which individuals might give the answers they think are expected rather than answers that reflect their true thoughts and behaviors.

Finally, the use of PLS–SEM, although robust and widely employed, has limitations. For instance, it assumes linear relationships among the constructs, which may not always hold. Thus, the results should be interpreted with these limitations and assumptions in mind. However, these do not undermine the study's contributions, but suggest future research avenues

CHAPTER 5

DATA ANALYSIS AND RESULTS

5.1 Data and Analytical Tools Employed

5.1.1 Source of Data

This chapter begins by discussing the data sources and analytical tools employed in this study. The data used in this research were collected through a survey conducted in Thailand. The survey's respondents were members of the FCC system. They were identified and accessed using the snowball sampling technique. Snowball sampling is a non-probability sampling technique typically used when the population is difficult to reach. This method was chosen because of its ability to leverage existing connections to access and recruit potential respondents who are part of Thailand's food cold chain system. It involves identifying a small pool of initial respondents, who then recommend other informants who meet the research criteria, creating a "snowball" effect.

The survey employed was designed to capture a wide range of data regarding participants' experiences, activities, and perceptions related to the FCC system. The collected data are both quantitative and qualitative, providing rich insights into the operations of the FCC in Thailand.

To ensure the validity and reliability of the data, several measures were implemented during the data collection process. These included pre-testing the survey on a small sample of respondents, clarifying any ambiguous questions, and regularly checking for any inconsistencies or errors in the responses. The result is a comprehensive dataset that provides a robust foundation for subsequent analysis.

5.1.2 Analytical Tool

After data collection, the analysis was conducted using SmartPLS 4, a widely utilized software for analyzing PLS–SEM. SmartPLS 4 was chosen due to its robustness in handling complex models, its ability to handle small- to medium-sized samples, and its flexibility in assuming data distributions. This software is also user friendly and offers a wide range of tools for data analysis, visualization, and reporting.

Within SmartPLS 4, analyses were conducted with the research objectives, including assessing the measurement model and the structural model, determining the significance of path coefficients, calculating effect sizes, and evaluating R-squared values. Each of these analyses provided unique insights into the relationships between constructs, the impact of certain factors on others, and the overall explanatory power of the model. Throughout the analysis, the principles of rigorous and transparent research were adhered to, ensuring that the results were both reliable and valid.

5.1.3 Respondent Demographics

The demographic profiles of respondents provide a crucial context for the study because they allow a nuanced interpretation of the results. Understanding the background of the respondents can illustrate their perceptions and responses, thus enriching the analysis. Moreover, demographic profiles help identify potential patterns or trends that might exist among demographic groups.

In this study, a diverse range of respondents participated, all of whom were members of Thailand's food cold chain system. This section provides an overview of the demographic profile of the subjects, which includes years of experience, organization size, operation location, organization role, and respondent role in the organization (Table 5.1).

Among the 226 individuals surveyed, most have one to five years of experience, accounting for 36% (82 respondents), closely followed by those with less than one year of experience at 31% (69 respondents). Those with more than 10 years and six to 10 years of experience represent 17% (39 respondents) and 16% (36 respondents), respectively. Regarding organization size, most informants were employed by small organizations (51%; 116 respondents), with 35% in medium-sized (79 respondents) and 14% in large organizations (31 respondents). In terms of operation location, a

significant majority, 72% (162 respondents), operate at a local or regional level, while 22% (49 respondents) are national, and 7% (15 respondents) are international. Regarding roles within organizations, the largest groups were food processors (32%; 72 respondents) and retailers (24%; 54 respondents), with others (19%; 43 respondents), distributors (12%; 27 respondents), and food suppliers (13%; 30 respondents) making up the remainder. As for informants' roles, the distribution was as follows: 30% at the management or executive level (68 respondents), 31% in other roles (69 respondents), 20% in operations or production (46 respondents), 12% in supply chain or logistics (28 respondents), and 7% in quality assurance or control (15 respondents).

Table 5.1 Respondent Demographic Profile

Demographic Profile	Frequency	Percentage
Experience		
1–5 years	82	36%
6–10 years	36	16%
Less than 1 year	69	31%
More than 10 years	39	17%
Organization Size		
Large	31	14%
Medium	79	35%
Small	116	51%
Operation Location		
International	15	7%
Local/Regional	162	72%
National	49	22%
Organization Role		
Distributor	27	12%
Food Processor	72	32%
Food Supplier	30	13%
Retailer	54	24%

Demographic Profile	Frequency	Percentage
Others	43	19%
Respondent Role		
Management/Executive Level	68	30%
Operations/Production	46	20%
Others	69	31%
Quality Assurance/Control	15	7%
Supply Chain/Logistics	28	12%
Grand Total	226	100%

5.2 Validity and Reliability Measures

5.2.1 Reliability Measures

The reliability of this model can be evaluated through three measures: Cronbach's alpha, composite reliability (ρ_a), and composite reliability (ρ_c). The results for each of these reliability measures for each construct in the model are presented in Table 5.2.

Cronbach's alpha was used to assess the internal consistency of the items within each construct. For the constructs in this study, all Cronbach's alpha values were notably high. Specifically, the Cronbach's alpha values are 0.88 for FCC Infrastructure, 0.956 for FCC Integration, 0.962 for FCCP, 0.922 for Partners' Performance, 0.959 for Sustainability Orientation, and 0.95 for Value Addition. These values, all of which were notably above the recommended threshold of 0.70, indicated a high level of internal consistency among the items within each construct.

Composite reliability (ρ_a) is another measure used to assess the reliability of constructs. For the constructs in this study, the ρ_a values were uniformly strong: 0.891 for FCC Infrastructure, 0.957 for FCC Integration, 0.963 for FCCP, 0.923 for Partners' Performance, 0.959 for Sustainability Orientation, and 0.95 for Value Addition. These values suggest that the constructs exhibit strong internal consistency, as they all surpass the commonly recommended threshold of 0.70.

The third measure of reliability examined in this study was composite reliability (ρ_c). In this study, the ρ_c values for the constructs are as follows: 0.917 for FCC

Infrastructure, 0.962 for FCC Integration, 0.967 for FCCP, 0.941 for Partners' Performance, 0.965 for Sustainability Orientation, and 0.96 for Value Addition. Similar to the other reliability measures, these values were all above the generally accepted threshold of 0.70, indicating strong reliability within each construct.

Table 5.2 Reliability Measures of the FCCP Model

Construct	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)
FCC Infrastructure	0.88	0.891	0.917
FCC Integration	0.956	0.957	0.962
Food Cold Chain Performance	0.962	0.963	0.967
Partners' Performance	0.922	0.923	0.941
Sustainability Orientation	0.959	0.959	0.965
Value Addition	0.95	0.95	0.96

5.2.2 Convergent Validity Measures

In terms of convergent validity, the average variance extracted (AVE) for each construct was calculated and is presented in Table 5.3. AVE values for all constructs, ranging from 0.717 for FCC Integration to 0.801 for Value Addition, exceeded the recommended threshold of 0.5, suggesting a high level of convergent validity. Specifically, the AVE for FCC Infrastructure was 0.734. For FCCP it was 0.727, for Partners' Performance it was 0.763, for Sustainability Orientation it was 0.777, and for Value Addition it was 0.801.

Table 5.3 Average Variance Extracted (AVE) of the FCCP Model

Construct	Average Variance Extracted (AVE)
FCC Infrastructure	0.734
FCC Integration	0.717
Food Cold Chain Performance	0.727
Partners' Performance	0.763
Sustainability Orientation	0.777
Value Addition	0.801

Through a bootstrapping process with 5,000 sub-samples, the significance of outer model loadings was estimated and analyzed (Table 5.4). These loadings represent the strength of the relationship between the indicators and their corresponding latent constructs. As per the table, all the outer loadings are significantly high, with the smallest loading being 0.782 (FCP2) and the largest being 0.915 (VA4). These loadings are well above the commonly recommended threshold of 0.7, indicating that each indicator is strongly representative of its respective latent construct. Additionally, the T statistics for all these loadings are markedly high, and the P values are consistently 0.000, further confirming the reliability and validity of these indicators.

Table 5.4 Outer Loadings of the FCCP Model

Indicator	Loadings	T Statistics	P Values
FCP1	0.808	29.256	0.000
FCP10	0.901	54.36	0.000
FCP12	0.844	31.185	0.000
FCP2	0.782	24.821	0.000
FCP3	0.855	45.111	0.000
FCP4	0.872	47.544	0.000
FCP5	0.894	58.079	0.000
FCP6	0.85	32.163	0.000

Indicator	Loadings	T Statistics	P Values
FCP7	0.835	31.656	0.000
FCP8	0.874	51.062	0.000
FCP9	0.86	38.952	0.000
IF1	0.846	32.26	0.000
IF2	0.845	30.479	0.000
IF3	0.865	40.319	0.000
IF4	0.871	40.812	0.000
IN10	0.823	32.234	0.000
IN11	0.844	31.139	0.000
IN13	0.869	39.993	0.000
IN14	0.848	36.96	0.000
IN2	0.843	31.292	0.000
IN4	0.861	35.804	0.000
IN5	0.864	37.039	0.000
IN7	0.807	24.25	0.000
IN8	0.865	34.495	0.000
IN9	0.843	29.202	0.000
PP1	0.855	38.626	0.000
PP2	0.887	56.462	0.000
PP3	0.875	45.424	0.000
PP4	0.877	45.669	0.000
PP5	0.872	44.26	0.000
SO1	0.867	46.614	0.000
SO2	0.861	36.68	0.000
SO3	0.889	53.595	0.000
SO4	0.901	45.245	0.000
SO5	0.882	41.426	0.000
SO6	0.893	46.594	0.000
SO7	0.847	27.475	0.000
SO8	0.909	59.656	0.000

Indicator	Loadings	T Statistics	P Values
VA1	0.88	49.123	0.000
VA2	0.911	60.659	0.000
VA3	0.884	38.96	0.000
VA4	0.915	59.156	0.000
VA5	0.893	45.765	0.000
VA6	0.885	40.609	0.000

In summary, the results from the average variance extracted (AVE) and the outer loadings strongly ensured the convergent validity of the model. All AVE values for the constructs exceed the recommended threshold of 0.5, and all outer loadings are significantly high and above the commonly suggested benchmark of 0.7.

5.2.3 Discriminant Validity Measure

The discriminant validity of the model can be assessed through three main indicators: the Heterotrait–Monotrait Ratio (HTMT), the Fornell–Larcker criterion, and the cross-loadings.

In the initial assessment of the discriminant validity of the model, two prominent measures were examined: the HTMT and the Fornell–Larcker criterion (Table 5.5). As a general rule of thumb, HTMT values should be lower than 0.90 to confirm discriminant validity. In the present model, all HTMT values were lower than the suggested threshold. However, there are some concerning values between FCC Integration and Value Addition, which was recorded at 0.891, and values between FCCP and Value Addition stood at 0.89. Turning to the Fornell–Larcker criterion, this approach involves a comparison of the square root of the average variance extracted (AVE) for each construct (shown on the diagonal of the matrix) with the correlations between the constructs (off the diagonal). For adequate discriminant validity to be established, the diagonal elements (square root of the AVE for each construct) should be greater than the off-diagonal elements in the corresponding rows and columns. In the current assessment, FCC Integration failed to meet the criteria, as it was highly correlated with FCCP and Value Addition. Similarly, FCCP was also highly correlated

with Value Addition. Hence, the discriminant validity of the FCCP model cannot be ensured and requires refinement.

Table 5.5 Initial Assessment of the Discriminant Validity of the FCCP Model

	IF	IN	FCP	PP	SO	VA
HTMT	-	-	-	-	-	-
FCC Infrastructure (IF)	-	-	-	-	-	-
FCC Integration (IN)	0.826	-	-	-	-	-
Food Cold Chain Performance (FCP)	0.729	0.894	-	-	-	-
Partners' Performance (PP)	0.634	0.768	0.844	-	-	-
Sustainability Orientation (SO)	0.535	0.772	0.752	0.743	-	-
Value Addition (VA)	0.74	0.891	0.89	0.759	0.747	-
Fornell–Larcker	-	-	-	-	-	-
FCC Infrastructure (IF)	0.857	-	-	-	-	-
FCC Integration (IN)	0.772	0.842	-	-	-	-
Food Cold Chain Performance (FCP)	0.684	0.865	0.845	-	-	-
Partners' Performance (PP)	0.577	0.727	0.797	0.873	-	-
Sustainability Orientation (SO)	0.505	0.745	0.724	0.700	0.881	-
Value Addition (VA)	0.687	0.857	0.852	0.713	0.714	0.895

To enhance the discriminant validity of the model, several indicators were identified as problematic due to their high cross-loadings with constructs that they are not supposed to measure. These high cross-loadings suggest a lack of clarity regarding the distinctiveness of the constructs. Therefore, a careful decision was made to remove certain indicators from the constructs.

A total of four indicators from two constructs were removed from the model, which include Interdepartmental Interactive Cooperation, Shared Vision and Objectives, Open Communication and Information Sharing with Partners from FCC Integration, and Environmental Impact from FCCP. Interdepartmental Interactive Cooperation (IN1) exhibited significant cross-loadings with FCCP and Value Addition. To resolve this issue, IN1 was removed. Similarly, Shared Vision and Objectives (IN3)

was removed due to its high cross-loadings with FCCP and Value Addition. In addition, Open Communication and Information Sharing with Partners (IN12) also exhibited significant cross-loadings with FCCP and Value Addition. Removing it would allow the construct to maintain its distinctiveness. Furthermore, Environmental Impact (FCP11) was intended to encompass aspects related to energy use, water use, and recycling within the FCCP construct. However, it was removed due to its significant cross-loadings with FCC Integration, Sustainability Orientation, and Partners' Performance constructs. This action was necessary because respondents might have perceived the indicator as relating to broader sustainability efforts and partner performance criteria, thereby compromising its distinctiveness and validity.

Following the removal of indicators that exhibited high cross-loadings, the discriminant validity of the model was re-evaluated. The reassessment was conducted using three major criteria: the Heterotrait–Monotrait Ratio (HTMT), the Fornell–Larcker criterion, and the cross-loadings.

The HTMT results show promising evidence of discriminant validity between the constructs. All HTMT values remained below the conservative threshold of 0.90, which reinforces the assertion that the constructs are empirically distinct. Moreover, the Fornell–Larcker criterion further supports the discriminant validity of the constructs in the model, as all the square root of the Average Variance Extracted (AVE) are observed to be greater than their highest correlation with any other construct in the model (Table 5.6). In summary, the revised model demonstrates robust discriminant validity, as the HTMT and Fornell–Larcker criteria are satisfactorily met. This is a critical step in affirming the psychometric properties of the model and setting a firm foundation for subsequent analyses.

Table 5.6 Final Assessment of Discriminant Validity of the FCCP Model

	IF	IN	FCP	PP	SO	VA
HTMT	-	-	-	-	-	-
FCC Infrastructure (IF)	-	-	-	-	-	-
FCC Integration (IN)	0.82	-	-	-	-	-

	IF	IN	FCP	PP	SO	VA
Food Cold Chain Performance (FCP)	0.73	0.87	-	-	-	-
		5				
Partners' Performance (PP)	0.63	0.76	0.83	-	-	-
	4	3	4			
Sustainability Orientation (SO)	0.53	0.76	0.72	0.74	-	-
	5	6	9	3		
Value Addition (VA)	0.74	0.87	0.88	0.75	0.74	-
		7	7	9	7	
Fornell–Larcker	-	-	-	-	-	-
FCC Infrastructure (IF)	0.85	-	-	-	-	-
	7					
FCC Integration (IN)	0.76	0.84	-	-	-	-
	4	7				
Food Cold Chain Performance (FCP)	0.68	0.84	0.85	-	-	-
	5	1	3			
Partners' Performance (PP)	0.57	0.71	0.78	0.87	-	-
	7	7	8	3		
Sustainability Orientation (SO)	0.50	0.73	0.70	0.70	0.88	-
	5	5	2	0	1	
Value Addition (VA)	0.68	0.83	0.84	0.71	0.71	0.89
	7	8	9	3	4	5

In addition to HTMT and the Fornell–Larcker criterion, the cross-loadings are a critical tool for assessing discriminant validity, which is established when an indicator loads significantly more on its intended construct than on any other construct in the model. Ideally, the difference between an indicator's loading on its intended construct and its cross-loading on other constructs should exceed 0.1. As depicted in Table 5.7, certain indicators in the revised model still exhibit a difference below the recommended threshold despite satisfying the HTMT and Fornell–Larcker criterion. These indicators include FCP1, FCP10, FCP4, IN13, IN2, and VA4. However, these indicators have been retained in the model due to the recognition of the complex and interrelated nature

of the constructs they represent. These constructs reflect multidimensional real-world phenomena that are inherently nonorthogonal, leading to shared variance. It is essential to note that each indicator has its highest loading on its assigned construct, indicating a stronger relationship with its intended construct relative to any other construct in the model. Hence, considering these aspects, the indicators must remain in the model to uphold its conceptual integrity and comprehensiveness, since removing them might jeopardize the theoretical foundation of the model and decrease the richness of insights it intends to provide. Hence, the cross-loading table largely confirms the discriminant validity of the model.

Table 5.7 Cross-Loadings After Indicators' Removal from the FCCP Model

Indicator	IF	IN	FCP	PP	SO	VA
FCP1	0.546	0.692	0.808	0.742	0.586	0.697
FCP10	0.636	0.774	0.901	0.677	0.67	0.79
FCP12	0.605	0.764	0.844	0.655	0.621	0.733
FCP2	0.559	0.682	0.782	0.784	0.59	0.625
FCP3	0.604	0.703	0.855	0.724	0.586	0.667
FCP4	0.591	0.765	0.872	0.616	0.596	0.731
FCP5	0.623	0.76	0.894	0.707	0.621	0.784
FCP6	0.561	0.702	0.85	0.71	0.638	0.703
FCP7	0.583	0.65	0.835	0.61	0.515	0.716
FCP8	0.546	0.67	0.874	0.602	0.558	0.769
FCP9	0.566	0.718	0.86	0.555	0.595	0.739
IF1	0.846	0.6	0.492	0.481	0.371	0.538
IF2	0.845	0.572	0.48	0.43	0.308	0.488
IF3	0.865	0.715	0.654	0.542	0.53	0.642
IF4	0.871	0.705	0.682	0.508	0.481	0.657
IN10	0.637	0.823	0.676	0.666	0.613	0.627
IN11	0.624	0.844	0.742	0.654	0.628	0.715
IN13	0.662	0.869	0.736	0.607	0.671	0.771
IN14	0.628	0.848	0.718	0.593	0.608	0.732

Indicator	IF	IN	FCP	PP	SO	VA
IN2	0.679	0.843	0.726	0.576	0.617	0.766
IN4	0.655	0.861	0.752	0.623	0.649	0.75
IN5	0.646	0.864	0.721	0.592	0.625	0.729
IN7	0.607	0.807	0.652	0.6	0.589	0.619
IN8	0.684	0.865	0.702	0.58	0.612	0.681
IN9	0.648	0.843	0.693	0.586	0.607	0.695
PP1	0.515	0.631	0.719	0.855	0.608	0.683
PP2	0.512	0.655	0.732	0.887	0.657	0.684
PP3	0.489	0.631	0.674	0.875	0.612	0.593
PP4	0.517	0.606	0.636	0.877	0.588	0.562
PP5	0.484	0.605	0.673	0.872	0.589	0.581
SO1	0.451	0.627	0.642	0.584	0.867	0.631
SO2	0.442	0.633	0.565	0.606	0.861	0.573
SO3	0.476	0.668	0.628	0.645	0.889	0.65
SO4	0.433	0.657	0.649	0.611	0.901	0.652
SO5	0.427	0.632	0.587	0.638	0.882	0.611
SO6	0.405	0.63	0.581	0.594	0.893	0.599
SO7	0.471	0.686	0.662	0.637	0.847	0.658
SO8	0.448	0.641	0.628	0.618	0.909	0.654
VA1	0.579	0.728	0.762	0.658	0.657	0.88
VA2	0.61	0.748	0.757	0.652	0.682	0.911
VA3	0.602	0.717	0.721	0.645	0.622	0.884
VA4	0.596	0.743	0.755	0.636	0.638	0.915
VA5	0.637	0.772	0.78	0.621	0.617	0.893
VA6	0.661	0.788	0.779	0.617	0.619	0.885

5.2.4 Multicollinearity Assessment

In assessing the potential for multicollinearity among the indicators, the variance inflation factor (VIF) was employed as a diagnostic tool. The VIF quantifies how much the variance of an estimated regression coefficient increases when predictors are correlated. Generally, a VIF above 10 indicates a severe multicollinearity problem.

According to the results in Table 5.8, all indicators in the model have VIF values below the critical threshold of 10, indicating no severe multicollinearity issues. The highest VIF value observed was 5.376 (FCP10), which was markedly below the suggested threshold. Noteworthy, FCP10, FCP8, and SO8 have VIF values of 5.38, 5.17, and 5.05, respectively, which are above the conservative threshold of 5, indicating a higher degree of collinearity than other indicators in the model. Nonetheless, given that these values do not exceed the critical threshold, they do not present an immediate concern for severe multicollinearity. Therefore, multicollinearity does not appear to be a significant issue in this model.

Table 5.8 Variance Inflation Factor (VIF) of the FCCP Model

Indicator	VIF	Indicator	VIF	Indicator	VIF
FCP1	2.773	IN10	3.314	SO1	3.676
FCP10	5.376	IN11	3.519	SO2	3.637
FCP12	3.795	IN13	3.663	SO3	4.462
FCP2	3.042	IN14	3.469	SO4	4.438
FCP3	3.768	IN2	3.324	SO5	4.513
FCP4	3.945	IN4	3.695	SO6	4.476
FCP5	4.159	IN5	3.396	SO7	2.785
FCP6	3.327	IN7	2.658	SO8	5.045
FCP7	3.335	IN8	3.864	VA1	3.625
FCP8	5.166	IN9	3.189	VA2	4.829
FCP9	4.545	PP1	2.855	VA3	3.389
IF1	2.464	PP2	3.367	VA4	4.503
IF2	2.505	PP3	2.99	VA5	4.055
IF3	2.218	PP4	3.273	VA6	3.678
IF4	2.283	PP5	2.997	VA6	3.678
				VA5	4.055
				VA6	3.678

5.3 Interpretation of the Structural Model

5.3.1 Explanation of the Structural Model

The structural model in this study reveals the intricate relationships among various constructs of the FCCP model, including FCC Infrastructure, FCC Integration, Partners' Performance, Sustainability Orientation, Value Addition, and FCCP. This model delineates both direct and indirect pathways through which these constructs interact. To ensure the robustness of the model estimation, a bootstrapping procedure with 5,000 subsamples was employed. This bootstrapping process is a resampling technique that provides a robust estimate of the distribution of the path coefficients, thus enabling a more reliable test of their statistical significance.

5.3.2 Analysis of Path Coefficients

The direct effect analysis revealed varying degrees of influence among the constructs under study (Table 5.9). FCC Infrastructure exerts a significant positive effect on Value Addition ($\beta = 0.144$, $p = 0.012$) but has no significant effect on either Food Cold Chain Performance ($\beta = 0.04$, $p = 0.414$) or Partners' Performance ($\beta = 0.122$, $p = 0.081$). FCC Integration strongly impacts Food Cold Chain Performance ($\beta = 0.293$, $p = 0.001$), Partners' Performance ($\beta = 0.336$, $p < 0.001$), and Value Addition ($\beta = 0.558$, $p < 0.001$). Notably, Sustainability Orientation appears to enhance Partners' Performance ($\beta = 0.392$, $p < 0.001$) and Value Addition ($\beta = 0.231$, $p = 0.0$), yet its effect on Food Cold Chain Performance turned out to be insignificant ($\beta = -0.001$, $p = 0.98$). Partners' performance also significantly affects Food Cold Chain Performance ($\beta = 0.294$, $p < 0.001$). Finally, Value Addition positively impacts Food Cold Chain Performance ($\beta = 0.367$, $p < 0.001$).

The indirect effect analysis offers nuanced insights, revealing the behind-the-scenes contributions of constructs through mediating variables (

Table 5.10). According to our results, FCC Infrastructure indirectly contributes to Food Cold Chain Performance ($\beta = 0.089$, $p = 0.017$), which highlights its mediated effect through other constructs. FCC Integration has a noteworthy indirect effect on Food Cold Chain Performance ($\beta = 0.303$, $p < 0.001$). The indirect effect of Sustainability Orientation on Food Cold Chain Performance ($\beta = 0.2$, $p < 0.001$) also proved to be significant.

Delving deeper, the specific indirect effect analysis provides further insight into the pathways through which each construct mediates these relationships (Table 5.11). Sustainability Orientation significantly affects FCCP through Value Addition ($\beta = 0.085$, $p = 0.001$) and Partners' Performance ($\beta = 0.115$, $p < 0.001$), establishing the mediating roles of these constructs with high statistical significance. FCC Infrastructure's impact on FCCP is significant when mediated by Value Addition ($\beta = 0.053$, $p = 0.031$) but not significant through Partners' Performance ($\beta = 0.036$, $p = 0.096$). FCC Integration positively and significantly affects FCCP via its impact on Partners' Performance ($\beta = 0.099$, $p = 0.004$) and Value Addition ($\beta = 0.205$, $p < 0.001$).

The total effect results integrate both the direct and indirect effects of the constructs, capturing their comprehensive impact on each other (Table 5.12). FCC Infrastructure's total effect on FCCP is moderate and significant ($\beta = 0.129$, $p = 0.031$). Although its direct effect on FCCP is not significant, the total effect on this variable becomes significant due to the influential indirect pathways through other constructs. The total effect of FCC Infrastructure on Partners' Performance ($\beta = 0.122$, $p = 0.081$) and Value Addition ($\beta = 0.144$, $p = 0.012$) remains the same, as there are no indirect effect influences. FCC Integration emerges as a notable contributor to Food Cold Chain Performance ($\beta = 0.597$, $p < 0.001$), Partners' Performance ($\beta = 0.336$, $p < 0.001$), and Value Addition ($\beta = 0.558$, $p < 0.001$). Sustainability Orientation's total effect is significant on Partners' Performance ($\beta = 0.392$, $p < 0.001$), Value Addition ($\beta = 0.231$, $p = 0.0$), and Food Cold Chain Performance ($\beta = 0.199$, $p = 0.003$), reinforcing its importance in the structural model. Last, due to the lack of an indirect effect, Partners' Performance still significantly affects Food Cold China Performance ($\beta = 0.294$, $p < 0.001$), and Value Addition positively impacts Food Cold Chain Performance ($\beta = 0.367$, $p < 0.001$).

In summary, Table 5.13 provides a comprehensive assessment of the hypotheses proposed in this study. FCC Infrastructure significantly influences FCCP and Value Addition, as demonstrated by the supported hypotheses 1 and 2. However, Hypothesis 3 suggested that the effect of FCC Infrastructure on Partners' Performance was not supported. FCC Integration consistently emerged as a potent construct since it positively impacts FCCP, Value Addition, and Partners' Performance, affirming hypotheses 4 through 6. Sustainability Orientation, underscored by hypotheses 7 to 9, has significant positive effects on all three of its proposed relationships. Finally, the relationships proposed in hypotheses 10 and 11, linking Value Addition and Partners' Performance to FCCP, were supported.

Table 5.9 Direct Effects of the FCCP Model

Relationships	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values
FCC Infrastructure -> Food Cold Chain Performance	0.040	0.041	0.049	0.816	0.414
FCC Infrastructure -> Partners' Performance	0.122	0.125	0.070	1.743	0.081
FCC Infrastructure -> Value Addition	0.144	0.147	0.058	2.499	0.012
FCC Integration -> Food Cold Chain Performance	0.293	0.288	0.089	3.296	0.001
FCC Integration -> Partners' Performance	0.336	0.334	0.090	3.716	0.000
FCC Integration -> Value Addition	0.558	0.555	0.081	6.910	0.000
Partners' Performance -> Food Cold Chain Performance	0.294	0.295	0.052	5.625	0.000
Sustainability Orientation -> Food Cold Chain Performance	-0.001	0.002	0.058	0.024	0.980
Sustainability Orientation -> Partners' Performance	0.392	0.392	0.066	5.935	0.000
Sustainability Orientation -> Value Addition	0.231	0.232	0.064	3.599	0.000
Value Addition -> Food Cold Chain Performance	0.367	0.366	0.078	4.725	0.000

Table 5.10 Indirect Effects of the FCCP Model

Relationships	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values
FCC Infrastructure -> Food Cold Chain Performance	0.089	0.091	0.037	2.393	0.017
FCC Integration -> Food Cold Chain Performance	0.303	0.303	0.069	4.399	0.000
Sustainability Orientation -> Food Cold Chain Performance	0.200	0.199	0.038	5.246	0.000

Table 5.11 Specific Indirect Effects of the FCCP Model

Relationships	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values
Sustainability Orientation -> Value Addition -> Food Cold Chain Performance	0.085	0.084	0.026	3.208	0.001
Sustainability Orientation -> Partners' Performance -> Food Cold Chain Performance	0.115	0.115	0.027	4.220	0.000
FCC Infrastructure -> Value Addition -> Food Cold Chain Performance	0.053	0.054	0.024	2.154	0.031
FCC Integration -> Partners' Performance -> Food Cold Chain Performance	0.099	0.099	0.034	2.874	0.004
FCC Infrastructure -> Partners' Performance -> Food Cold Chain Performance	0.036	0.037	0.022	1.666	0.096
FCC Integration -> Value Addition -> Food Cold Chain Performance	0.205	0.204	0.055	3.696	0.000

Table 5.12 Total Effects of the FCCP Model

Relationships	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values
FCC Infrastructure -> Food Cold Chain Performance	0.129	0.132	0.060	2.160	0.031
FCC Infrastructure -> Partners' Performance	0.122	0.125	0.070	1.743	0.081
FCC Infrastructure -> Value Addition	0.144	0.147	0.058	2.499	0.012
FCC Integration -> Food Cold Chain Performance	0.597	0.591	0.079	7.579	0.000
FCC Integration -> Partners' Performance	0.336	0.334	0.090	3.716	0.000
FCC Integration -> Value Addition	0.558	0.555	0.081	6.910	0.000
Partners' Performance -> Food Cold Chain Performance	0.294	0.295	0.052	5.625	0.000
Sustainability Orientation -> Food Cold Chain Performance	0.199	0.201	0.068	2.933	0.003
Sustainability Orientation -> Partners' Performance	0.392	0.392	0.066	5.935	0.000
Sustainability Orientation -> Value Addition	0.231	0.232	0.064	3.599	0.000
Value Addition -> Food Cold Chain Performance	0.367	0.366	0.078	4.725	0.000

Table 5.13 Hypotheses Testing Results of the FCCP Model

No.	Hypotheses	Direct Effect	Indirect Effect	Total Effect	T Statistics	P Values	Remarks
H1	FCC Infrastructure -> Food Cold Chain Performance	0.040	0.089	0.129	2.160	0.031	Supported
H2	FCC Infrastructure -> Value Addition	0.144		0.144	2.499	0.012	Supported
H3	FCC Infrastructure -> Partners' Performance	0.122		0.122	1.743	0.081	Not Supported
H4	FCC Integration -> Food Cold Chain Performance	0.293	0.303	0.597	7.579	0.000	Supported
H5	FCC Integration -> Value Addition	0.558		0.558	6.910	0.000	Supported
H6	FCC Integration -> Partners' Performance	0.336		0.336	3.716	0.000	Supported
H7	Sustainability Orientation -> Food Cold Chain Performance	-0.001	0.200	0.199	2.933	0.003	Supported
H8	Sustainability Orientation -> Value Addition	0.231		0.231	3.599	0.000	Supported
H9	Sustainability Orientation -> Partners' Performance	0.392		0.392	5.935	0.000	Supported
H10	Value Addition -> Food Cold Chain Performance	0.367		0.367	4.725	0.000	Supported
H11	Partners' Performance -> Food Cold Chain Performance	0.294		0.294	5.625	0.000	Supported

5.3.3 Understanding of Effect Sizes

The effect size of the model can be assessed through f-square values, which quantify the relative impact of each independent variable on the dependent variables in the model (Table 5.14). FCC Infrastructure has a minor effect on FCCP with an f-square of 0.003, a modest effect on Partners' Performance with an f-square of 0.015, and a moderate effect on Value Addition with an f-square of 0.032. This small effect size suggests that FCC Infrastructure may not be a critical determinant of Partners' Performance or FCCP, which could be due to the presence of other more significant factors. Alternatively, perhaps the impact is more indirectly mediated through other constructs. FCC Integration exerts a significant impact on FCCP with an f-square of 0.09, on Partners' Performance with an f-square of 0.069, and notably, a large effect on Value Addition with an f-square of 0.294. Partners' Performance significantly influences FCCP with an f-square of 0.187, indicating a substantial effect. Sustainability Orientation has a negligible impact on FCCP with an f-square of 0.000, a substantial effect on Partners' Performance with an f-square of 0.168, and a moderate effect on Value Addition with an f-square of 0.091. This negligible effect size of Sustainability Orientation on FCCP may be because its impact is largely mediated through other constructs, such as Value Addition or Partners' Performance. It can also reflect that FCCP is more sensitive to other operational or market factors. Last, value addition plays a marked role in affecting FCCP, with an f-square of 0.188 highlighting its strong influence. Importantly, these low or negligible f-square values are not necessarily indicative of unimportant relationships. In complex systems, such as structural equation models, some constructs might exert their influence more indirectly or under certain conditions that might not be fully captured by the current data and model specifications. Even small effects can be meaningful and valuable depending on the context, the scale of operations, and the objectives of the stakeholders involved.

Table 5.14 F-Square of the FCCP Model

Construct	IF	IN	FCP	PP	SO	VA
FCC Infrastructure	-	-	0.003	0.015	-	0.032
FCC Integration	-	-	0.09	0.069	-	0.294
Food Cold Chain Performance	-	-	-	-	-	-
Partners' Performance	-	-	0.187	-	-	-
Sustainability Orientation	-	-	0.000	0.168	-	0.091
Value Addition	-	-	0.188	-	-	-

5.3.4 Evaluation of R-squared Values

In the analysis of PLS–SEM, R-square values represent the relative predictive power of the model because it represents the proportion of variance in the dependent variables that is predictable from the independent variables. According to Falk and Miller (1992), this measure should be greater than 0.1 to be considered meaningful. Table 5.15 illustrates the R-square of each dependent variable in the FCCP model. Our model reported an R-Square of 0.816 for Food Cold Chain Performance (adjusted to 0.812), 0.586 for Partners' Performance (adjusted to 0.58), and 0.732 for Value Addition (adjusted to 0.729). Hence, we conclude that our model exhibits substantial predictive power for these constructs.

Table 5.15 R-Square of the FCCP Model

Construct	R-square	R-square Adjusted
Food Cold Chain Performance	0.816	0.812
Partners' Performance	0.586	0.58
Value Addition	0.732	0.729

5.4 Consideration of Model Fit and Goodness-of-Fit Measures

In evaluating the fit of our structural model, we employed fit indices and compared our estimated model to a saturated model, as displayed in Table 5.16. The results indicate a mixed level of fit based on the criteria suggested by Hu and Bentler

(1999). Specifically, the standardized root mean square residual (SRMR) was 0.053, which is well below the recommended threshold of 0.08, indicating a good fit of the model in terms of the residuals between the observed and predicted correlation matrices. Conversely, the normed fit index (NFI) was 0.791, which is below the stringent recommended threshold of 0.9 for an excellent model fit. However, it still represents a relatively strong comparative fit of the model, considering that this NFI value indicates that our proposed model accounts for nearly 80% of the improvement in fit over the null model. Moreover, since NFI is sensitive to sample size and model complexity, along with the context of our research design and the specific data at hand, this NFI value can be viewed as indicating a reasonably good and satisfactory fit between our model and the observed data. In addition, the chi-square values of the model for the saturated and estimated models were 2,536.254 and 2,537.444, respectively. This closeness also enhances the goodness of fit of our model, as the estimated model is almost as good as a perfect model (saturated model) in reproducing the observed data.

Table 5.16 Model Fit Summary of the FCCP Model

	Saturated Model	Estimated Model
SRMR	0.053	0.053
NFI	0.791	0.791
Chi-square	2,536.254	2,537.444

5.5 Special Case: Development of the Pilot Model

Before the finalization of our FCCP model, we engaged in the crucial step of creating a pilot model. This pilot model served as an initial blueprint and was instrumental in the foundational stages of this research. The purpose of this pilot model was to gain initial insights and test the relationships between key constructs: Sustainability Orientation, FCC Integration, Value Addition, and FCCP (Figure 5.1).

The development of the questionnaire involved a two-phase approach. First, a preliminary version was created by examining the relevant literature and consulting

FCC experts, including practitioners, academics, and research scientists. This initial version was refined based on the feedback received. In the second phase, the finalized questionnaire was distributed digitally to the target group, which are members of the FCC in Thailand, in 2023. The indicators were assessed using a 5-point Likert scale, where 1 indicates strong disagreement and 5 indicates strong agreement.

The measurement of sustainability orientation was derived from Kuckertz and Wagner's (2010) framework, which has gained widespread recognition and adoption. The measures for internal integration and inter-firm integration were derived from insights from Basnet (2013) and Cerchione, Centobelli, et al. (2018), respectively. For the value addition measurement, the findings from Shashi et al. (2017) were applied. Last, relying on the work of Aramyan et al. (2007) and Fattahi et al. (2013), we devise a measurement that could effectively assess FCCP.

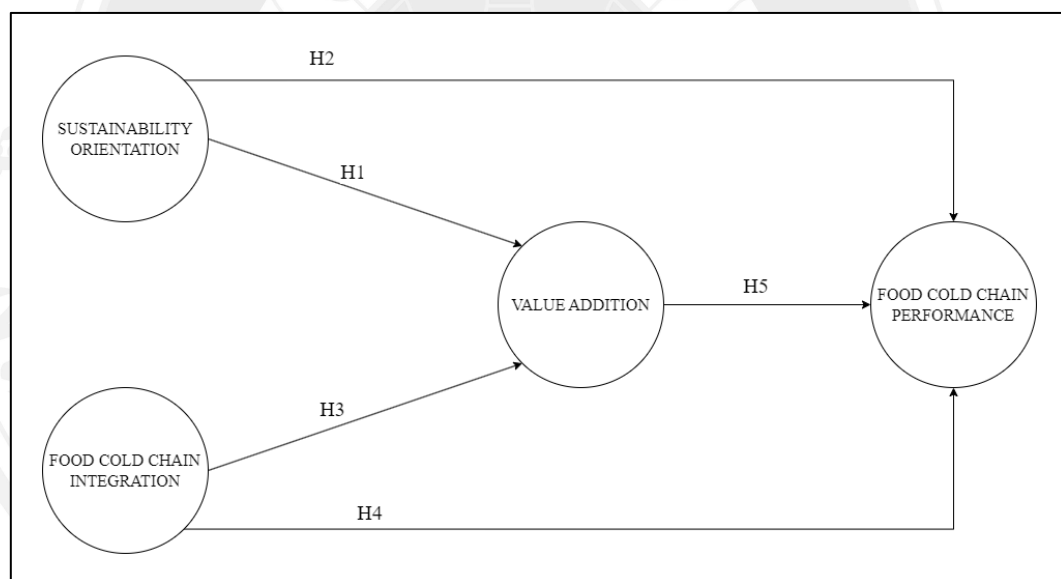


Figure 5.1 The Food Cold Chian Performance Model (Pilot)

Importantly, this pilot model utilized different indicators to measure these constructs compared to those in the final model. In particular, the indicators of this pilot model were later refined and utilized in the final FCCP model. Moreover, the dataset used for this pilot model diverged from that used in the final analysis. While the target respondents were consistent, being professionals in the FCC sector, the collected data

for this pilot phase were not exactly the same. This separate dataset was beneficial for avoiding overfitting and ensuring that the final model was not tailored excessively to specific data patterns.

At the end of the data collection process, 153 valid responses were collected, and the demographic profile of the respondents is demonstrated in Table 5.17. The results show that most individuals were relatively new to the field, with 41% having less than one year of experience, followed by 37% with one to five years of experience. Those with six to 10 years and more than 10 years of experience comprised 15% and 7% of the sample, respectively. In terms of organization size, a substantial proportion of the respondents, approximately 58%, were from small-sized organizations, 32% were associated with medium-sized organizations, and 10% were from large organizations. Regarding the operational location of these organizations, most respondents operated at a local or regional level, with 71%, while 20% had a national reach, and 9% operated internationally. In the context of organizational roles within the FCC, 32% of the informants were from the food processing business, closely followed by 28% working as retailers. Food suppliers and distributors were represented by 18% and 13% of the subjects, respectively, with the remaining 9% falling under the other categories. As for the respondents' roles within their organizations, a significant portion, 37%, were involved in operations or production, with 26% holding management or executive-level positions. The study also included those in quality assurance (14%), supply chain or logistics roles (16%), and other roles, which accounted for 7% of respondents.

Table 5.17 Respondents' Demographic Profile of the Pilot Model

Demographic Profile	Frequency	Percentage
Experience		
1–5 years	57	37%
6–10 years	23	15%
Less than 1 year	63	41%
More than 10 years	10	7%
Organization Size		

Demographic Profile	Frequency	Percentage
Large	15	10%
Medium	50	32%
Small	88	58%
Operation Location		
International	14	9%
Local/Regional	109	71%
National	30	20%
Organization Role		
Distributor	20	13%
Food Processor	49	32%
Food Supplier	28	18%
Retailer	43	28%
Others	13	9%
Respondent Role		
Management/Executive Level	40	26%
Operations/Production	56	37%
Others	11	7%
Quality Assurance/Control	22	14%
Supply Chain/Logistics	24	16%
Grand Total	57	100%

The analysis started with evaluating the validity and reliability of this pilot model. Cronbach's alpha and composite reliability (CR) were examined to ensure the construct reliability of the model, in which all constructs' Cronbach's alpha and CR reached the threshold of 0.7 and 0.6, respectively (Table 5.18). The convergent validity was also considered adequate. The results also revealed that the AVE of all constructs passed the threshold of 0.5, as follows: Sustainability Orientation (0.693), FCC Integration (0.707), Value Addition (0.765), and FCCP (0.722). The convergent validity of this model was also ensured through the examination of outer loadings, which showed that all loadings were above the commonly recommended threshold of 0.7 and were statistically significant (Table 5.19) Using the Fornell–Larcker criterion,

we can ensure the discriminant validity of the model, as the square root of the AVE for each construct is greater than its correlations with other constructs (Table 5.20) Initially, the pilot model failed to pass the criterion due to the high cross-loadings of several indicators, yet the criteria were met after systematically removing those problematic indicators while ensuring the integrity of the constructs.

Table 5.18 Construct Reliability and Validity of the Pilot Model

Construct	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
FCC Integration	0.958	0.964	0.707
FCC Performance	0.957	0.963	0.722
Sustainability Orientation	0.91	0.931	0.693
Value Addition	0.956	0.963	0.765

Table 5.19 Outer Loadings of the Pilot Model

Indicator	Loadings	T Statistics	P Values
FCCP10	0.856	28.513	0.000
FCCP11	0.852	27.625	0.000
FCCP14	0.871	27.794	0.000
FCCP15	0.863	33.894	0.000
FCCP16	0.865	27.511	0.000
FCCP17	0.823	20.821	0.000
FCCP19	0.855	25.312	0.000
FCCP4	0.826	23.411	0.000
FCCP6	0.852	29.833	0.000
FCCP9	0.833	23.301	0.000
IN13	0.797	20.479	0.000

Indicator	Loadings	T Statistics	P Values
IN14	0.807	20.496	0.000
IN15	0.864	38.022	0.000
IN18	0.823	24.481	0.000
IN2	0.759	16.574	0.000
IN20	0.880	39.737	0.000
IN21	0.873	39.243	0.000
IN23	0.872	30.705	0.000
IN24	0.861	25.902	0.000
IN25	0.880	37.566	0.000
IN27	0.822	24.792	0.000
SO1	0.741	16.006	0.000
SO2	0.810	21.651	0.000
SO3	0.837	24.698	0.000
SO4	0.899	42.307	0.000
SO5	0.820	20.196	0.000
SO6	0.879	30.358	0.000
VA12	0.865	30.759	0.000
VA15	0.864	30.076	0.000
VA17	0.901	41.507	0.000
VA18	0.904	44.133	0.000
VA19	0.873	29.89	0.000
VA4	0.855	31.828	0.000
VA5	0.864	35.106	0.000
VA8	0.871	22.502	0.000

Table 5.20 Fornell–Larcker Criterion of the Pilot Model

Construct	FCC Integration	FCC Performance	Sustainability Orientation	Value Addition
FCC Integration	0.841	-	-	-
FCC Performance	0.834	0.850	-	-
Sustainability Orientation	0.705	0.710	0.833	-
Value Addition	0.835	0.847	0.733	0.875

In terms of predictive power, the pilot model reported an R-Square of 0.735 for Value Addition and 0.79 for FCCP, which surpasses the 0.1 minimum threshold (Table 5.21). This pilot model also displays an adequate goodness of fit, as our result shows that the SRMR of 0.048 is significantly lower than the ceiling of 0.08 and the NFI of 0.811, which is lower than the recommended threshold of 0.9, but still considered acceptable (Table 5.22) Hence, we can ensure the predictive power and goodness of fit of this pilot model.

Table 5.21 R-Square of the Pilot Model

Construct	R-Square	R-Square Adjusted
FCC Performance	0.776	0.771
Value Addition	0.739	0.735

Table 5.22 Model Fit Summary of the Pilot Model

	Saturated Model	Estimated Model
SRMR	0.048	0.048
NFI	0.811	0.811

Through the bootstrapping process with 5,000 sub-samples, the analysis reveals significant relationships between constructs in the model (Table 5.23). Hypothesis 1, which posited a direct effect of sustainability orientation on value addition, was

supported, as indicated by a direct effect of 0.285 (t-value = 3.300, p-value = 0.001). Hypothesis 2, examining the total effect of Sustainability Orientation on Food Cold Chain (FCC) Performance, was also supported, with a direct effect of 0.117 and an indirect effect of 0.126, resulting in a total effect of 0.243 (t-value = 3.107, p-value = 0.002). Hypothesis 3, suggesting a direct effect of FCC integration on value addition, was strongly supported, indicated by a direct effect of 0.634 (t-value = 7.521, p-value = 0.000). Hypothesis 4 proposed that FCC integration has a substantial total effect on FCCP, which was confirmed with a direct effect of 0.382, an indirect effect of 0.281, and a total effect of 0.662 (t-value = 9.624, p-value = 0.000). Last, Hypothesis 5, positing a direct effect of value addition on FCCP, was also supported by a direct effect of 0.443 (t-value = 4.983, p-value = 0.000). These results provide strong evidence of positive and significant relationships between the constructs in the model.

In conclusion, the development of the pilot model has proven to be a valuable and instrumental step in this research. The model is robust and demonstrates that the fundamental relationships proposed within it are empirically confirmed. The results show that the relationships between Sustainability Orientation, FCC Integration, Value Addition, and Food Cold Chain Performance were substantiated with significant empirical evidence, thereby confirming the construct validity and the theoretical underpinnings of these relationships.

Furthermore, the successful validation of the pilot model has paved the way for the development of a complete conceptual model. The full FCCP model will encompass two additional constructs: FCC Infrastructure and Partners' Performance. The inclusion of these constructs is expected to enhance the model's ability to capture the dynamics of FCCP and to provide a more comprehensive understanding of the factors that drive it.

Table 5.23 Hypotheses Testing Result of the Pilot Model

No.	Hypotheses	Direct Effect	Indirect Effect	Total Effect	T-Values	P-Values	Remarks
H1	Sustainability Orientation → Value Addition	0.285	0.000	0.285	3.300	0.001	Supported
H2	Sustainability Orientation → FCC Performance	0.117	0.126	0.243	3.107	0.002	Supported
H3	FCC Integration → Value Addition	0.634	0.000	0.634	7.521	0.000	Supported
H4	FCC Integration → FCC Performance	0.382	0.281	0.662	9.624	0.000	Supported
H5	Value Addition → FCC Performance	0.443	0.000	0.443	4.983	0.000	Supported

CHAPTER 6

DISCUSSION AND IMPLICATIONS

This research delves into the key components of the food cold chain performance (FCCP) model's key components. Unlike previous studies, which focused only on specific aspects of FCC systems, this research evaluates the interdependent relationships between critical components. These components include FCC Infrastructure, FCC Integration, Sustainability Orientation, Value Addition, Partners' Performance, and FCCP. The research introduces a comprehensive model of FCCP, expanding our understanding of how enhancing particular components can have an impact on overall performance.

6.1 Key Findings on the FCCP Model

An analysis of the FCCP model revealed several key findings that underscore the intricate dynamics of FCC operations. Drawing upon the empirical results in the previous chapter, this section delves deeper into the intricate relationships among the constructs and their cumulative effects on the overall performance of the FCC. These findings illuminate the roles that infrastructure, integration, sustainability orientation, partners' performance, and value addition play within the cold chain, thus highlighting critical leverage points that can be harnessed to optimize the performance of the FCC.

First, the FCC infrastructure shows substantial and significant positive direct effects on value addition. This implies that having a well-established infrastructure contributes directly to the value-addition process of the FCC. Noteworthy, infrastructure, in contrast to our expectations, does not directly affect FCCP or partners' performance, highlighting its role as more of an enabler rather than a direct driver of performance. Through an analysis of indirect effects, clearly, infrastructure indirectly improves the performance of the FCC through other constructs, which further

highlights the importance of infrastructure in supporting other systems and processes. Further analysis of the specific indirect effects reveals that, when mediated by value addition, infrastructure significantly impacts FCC performance, indicating that infrastructure's role in enhancing cold chain performance is particularly tied to how it enables value-adding practices in the chain. In contrast, the results show that it has no marked impact when mediated through partners' performance. Ultimately, while infrastructure may not directly impact chain performance, it still has a notable indirect effect through other constructs.

FCC integration emerged as the most potent construct in the FCCP model, exerting strong positive impacts on FCCP, partners' performance, and value addition. This strong direct relationship indicates that integration is critical for achieving superior performance in the FCC. Further analysis also demonstrated that integration has a noteworthy indirect effect on food cold-chain performance, signifying its role in the operation of the chain.

Compared to other factors, sustainability orientation presents a nuanced and intricate perspective. Although it greatly enhances partners' performance and value addition, it surprisingly exhibits a nearly negative direct effect on FCCP, although the relationship is insignificant. This finding suggests that the focus on sustainability may not directly translate into immediate performance improvements, possibly due to the costs or operational changes associated with implementing sustainable practices. However, the indirect effect of sustainability orientation on FCCP proved important through the mediating effect of value addition and partners' performance. Despite its direct negative relationship with FCCP, its total effect becomes significantly positive, affirming the foundational importance of sustainability orientation to the structural model.

The results also illustrate that Partners' Performance displays a significantly strong positive effect on FCC performance, suggesting that the performance of partners in the cold chain is inherently linked to the overall cold chain's performance. Value addition also emerges as a critical construct that augments FCC performance. This indicates that the processes of adding value to products within the cold chain are fundamental for enhancing the chain's overall performance. The analysis shows that value addition plays a significant role in mediating the relationship between several

constructs (e.g., sustainability orientation and FCC infrastructure) and FCCP, indicating its central role in the cold chain ecosystem.

In summary, these findings emphasize that, while certain constructs, such as FCC integration, are powerful direct influencers of performance, others, such as FCC infrastructure and sustainability orientation, exert their influence indirectly and are nonetheless pivotal for the overall performance of the FCC. Hence, achieving optimal cold chain performance is not simply a matter of enhancing individual components in isolation but requires a harmonized, systemic approach that accounts for the intricate interplay between constructs.

6.2 Relevance to the Thai Food Cold Chain

In the Thai food industry, our analysis suggests that infrastructure demonstrates a strong, positive, and significant effect on the value-addition process of the FCC. This result provides evidence that a well-established infrastructure is essential for the chain's value-adding process. Notably, most respondents were from small organizations, often operating at local or regional levels. For such entities, investments in infrastructure likely focus on immediate needs that directly contribute to adding value to products. Given the dominance of small firms in our respondent profile, it is possible that these firms may not fully recognize the importance of infrastructure in enhancing overall cold chain performance, resulting in an insignificant direct relationship between infrastructure and overall performance. The seemingly limited scope of their infrastructure investments might be due to a narrower focus on immediate tangible returns directly linked to value addition rather than broader operational efficiencies or partners' performance. This uneven distribution in respondent profiles may be the main reason that infrastructure shows no direct effect on FCC or partners' performance.

Moreover, the respondent roles illuminate another important angle. With only 30% of respondents occupying the managerial or executive level, the understanding and prioritization of infrastructure investments may be influenced. Those in managerial positions are likely to have a broader view of organizational strategy and might be more attuned to the long-term benefits of robust infrastructure. However, given the limited representation of this group in the sample, this perspective might not be sufficiently

reflected in the findings. In addition, considering that many respondents are relatively new to the industry, their understanding of infrastructure's potential to directly impact chain performance may not be fully grasped or capitalized on. Because their roles might not involve decision making at a strategic level, their responses could further underscore why infrastructure's role as a vital enabler emerged so strongly in our analysis rather than as a direct driver of performance. Nevertheless, our results further enhance the fact that infrastructure functions more as an enabler than as a direct performance driver. This could imply that, in Thailand, the true strength of infrastructure investments is realized when they facilitate processes that add value to the products in the cold chain.

In the Thai FCC, integration is considered a key construct, exhibiting strong positive impacts on FCCP, partners' performance, and value addition. The results suggest that integration, which encompasses coordinated actions, information sharing, and relationship management within and between firms, is crucial for achieving superior performance in the Thai FCC. The importance of integration is likely enhanced due to the local and regional focus of a significant majority of Thai cold chain operators, as indicated by 72% of respondents. For these operators, efficient coordination between different stages of the cold chain is paramount for ensuring product quality and reducing losses, making integration a critical performance driver. Given that the respondents are mainly from small and medium enterprises (SMEs), this finding further reflects these organizations' resource constraints, which make integration beneficial and essential for their survival and competitiveness in the industry. Interestingly, FCC integration also has a noteworthy indirect effect on FCCP, particularly through its impact on partners' performance and value addition. Hence, integration plays a crucial role in Thailand, serving two distinct but equally important purposes. First, it directly contributes to performance improvement, helping businesses and organizations achieve greater efficiency and effectiveness. Second, it facilitates the formation of valuable partnerships and collaborations, which can be essential for achieving collective goals. Therefore, a comprehensive understanding of the role of integration in improving food cold chain performance is essential for success in Thailand's FCC.

The study also reveals a complex view of the sustainability orientation of practitioners in the Thai FCC. While it improves the performance and value of partners,

it appears to have a somewhat negative impact on the performance of the cold chain, itself, although this effect is not significant. The reason for this outcome may be that Thailand is a developing economy, and the respondents to the survey have limited experience working in smaller companies. Consequently, they may be more focused on the immediate costs and changes required to implement sustainable practices than on the benefits that could be gained. Many organizations, especially SMEs, which comprise a large portion of respondents, may perceive the adoption of sustainability as more of a hindrance than a benefit to their performance. This could be caused by the initial expenses of sustainable technologies or practices or a lack of understanding and experience in carrying out these practices efficiently. However, the indirect effects of sustainability orientation on FCCP prove significant, as it notably refines performance through value addition and partners' performance. Thus, sustainability orientation is considered an integral component of enhancing performance, even if the correlation may not be immediately apparent. Because cold chain operators in Thailand continue to develop and expand their operations, embracing a sustainability orientation will prove increasingly imperative for achieving success on a comprehensive level.

In the Thai FCC, value addition is considered a crucial element that ameliorates its performance. Hence, anything that enhances product quality, extends shelf life, or increases product appeal is essential for the competitiveness and effectiveness of cold chain operations in Thailand. Since many respondents are either food processors or retailers, it makes sense that they focus on value addition to differentiate their products in a competitive market. Value addition is not just about making money right away, since it also plays a crucial role as a mediator in the relationship between FCC performance and other factors, including infrastructure, chain integration, and sustainability orientation. This highlights how vital value addition is in Thailand's overall cold chain ecosystem. Improvements in sustainable practices or infrastructure may not lead to immediate performance gains. However, they can enable processes that add significant value to products, which heightens overall performance.

Partners' performance has a significant impact on food cold chain operations in Thailand, highlighting the interdependent nature of the process. Because many respondents come from smaller organizations that operate locally or regionally, the reliability and effectiveness of partners can significantly influence overall performance.

In this model, there is no indirect effect observed between partners' performance and other constructs, which emphasizes the direct role it plays in influencing cold chain performance. This may reflect the collaborative nature of the Thai industry, where the cold chain involves various stakeholders, such as farmers, processors, distributors, and retailers. Solid and reliable partnerships are vital for achieving high performance because the performance of one partner can affect the entire chain. The demographic data show that a significant proportion of respondents hold managerial or executive roles, further highlighting the importance of effective collaborations and partnerships in shaping their strategies and their organizations' overall performance.

6.3 Alignment of Findings with the Literature

While the current study found no significant direct effect of FCC infrastructure on FCCP, it uncovered a significant indirect effect through value addition. This lack of a direct relationship contrasted with several pieces of literature that underscored the vital role of infrastructure in the FCC. For instance, Kitinoja (2013) emphasized that a well-developed FCC infrastructure is a prerequisite for improving chain performance. Similarly, Joshi et al. (2009); Zia (2007) highlighted the lack of adequate infrastructure as a significant bottleneck in the FCC. However, congruent with Aung and Chang (2014b), infrastructure can have a significant impact on the chain's overall performance through the mediating effect of value addition. However, this discovery is unsurprising, since several studies have proposed similar concepts. Bosona and Gebresenbet (2013) pointed out that an effective food traceability system adds value in terms of quality assurance, thereby enhancing customer satisfaction and ultimately resulting in FCCP. The importance of the effect of infrastructure on value addition was also highlighted by Rediers et al. (2009), who stated that the absence of infrastructure can obstruct value-addition efforts. This insight suggests a more complex and mediated relationship between infrastructure and cold chain performance than has traditionally been depicted, bridging a gap in previous research and providing a nuanced understanding of the dynamics within the FCC. One reason for the insignificance of infrastructure might stem from the recent global COVID-19 pandemic. Due to the pandemic, organizations shifted their focus toward enhancing operational performance, resilience, and digital

transformation rather than investing in infrastructure improvements (Fonseca & Azevedo, 3920).

In the current study, integration within the FCC demonstrated a significant and strong positive relationship with FCCP. This relationship is particularly potent when mediated through value addition, highlighting the central role of integration in bolstering performance, a finding that aligns with the prior literature (Shashi et al., 2017; Stank et al., 2001). Notably, among the exogenous factors explored in this research, integration stands out as having the most substantial positive impact on performance, reinforcing its critical importance. This resonates with prior studies that underscored the role of integration in achieving competitive advantages and boosting operational and financial performance (Chang et al., 2016; Jie et al., 2013). Furthermore, this study revealed that integration has a highly positive effect on value addition within the FCC. This finding is substantiated by the existing literature (Zhou & Benton, 2007), which emphasizes the benefits of integration for enabling seamless cooperation among chain members. This, in turn, leads to superior service to customers and the consistent delivery of high-quality products, thereby enhancing value across the entire FCC.

Contrary to expectations, this study finds that sustainability orientation does not directly impact FCCP. While the direct effect of sustainability orientation on overall FCCP in this study is negative and insignificant, it is essential to highlight that sustainability orientation still plays a pivotal role when considering the total effect. This role is mediated through value addition and, more substantially, through partners' performance. This introduces a novel insight that diverges from some previous literature that often presents sustainability practices as directly beneficial for performance. One possible explanation for the observed insignificant direct relationship between sustainability orientation and FCCP may stem from the respondent demographics in this study. Because most of our respondents hail from small firms with fewer than five years in the industry, they may have low levels of familiarity or engagement with sustainability practices, and they might perceive and report the impacts of these practices differently. A small proportion of respondents with managerial roles who generally recognize the importance of sustainability issues could also have caused the deviation in our result. In addition, Thailand's cultural and

regulatory context could play a significant role in this relationship. Another possible explanation may be that Thailand's sustainability standards and practices are in various stages of development and adoption across sectors and regions, affecting respondents' perspectives and reported outcomes.

Moreover, our findings suggest the critical role of value addition and partners' performance in mediating the effect of sustainability orientation on overall chain performance. This substantial mediating effect through partners' performance is particularly noteworthy. One potential explanation for this could be that a sustainability orientation encourages the development of closer, more collaborative relationships with partners in the supply chain. According to Hollos et al. (2012), suppliers' sustainable practices positively affect the performance of their downstream chain members. Similarly, Cerchione, Centobelli, et al.'s (2018) empirical study illustrates that a sustainability orientation requires the mediating role of sustainable practice to affect performance. Furthermore, sustainability-oriented firms may impose certain environmental and social criteria on their partners, as Beske et al. (2014) noted. This could lead to process improvements, greater efficiency, and enhanced performance across the chain as partners align with these criteria. Regarding value addition, our findings also align with Hsu et al. (2022), who confirmed the positive effect of corporate social responsibility (CSR) on value addition in the supply chain. Their study emphasized that the benefits of CSR extend from focal firms to other members of the chain, supporting the idea of sustainability as a driver of value addition.

As the direct effect of several factors on food cold chain performance is observed to be insignificant, the mediating roles of value addition and partners' performance are pivotal and cannot be overlooked. These mediators reveal the nuanced, indirect ways through which infrastructure and sustainability orientation influence the overall performance of the FCC. Notably, value addition emerges as a significant and strong mediator of this relationship, substantiated by numerous studies highlighting its crucial role in enhancing firm performance (Aworh, 2015; Martinez, 2014; Shashi et al., 2017). These practices, encompassing efficient chain management and temperature control along the cold chain, enhance product quality and quantity, which is directly tied to customer satisfaction and repeat purchases (Aung & Chang, 2014a). Higher customer satisfaction, in turn, refines overall FCCP, with value-addition practices

leading to waste minimization, reduced costs, and shorter lead times, granting firms a competitive advantage (Alonso & Northcote, 2013; Aworh, 2015; Chang et al., 2016). Partners' performance, while also serving as a significant mediator, directly affects FCCP, which is not as potent as value addition. Nonetheless, our findings align with several studies because the efficient performance of one member of the FCC does indeed promote the performance of others, substantiating the overall performance of the entire chain (Ageron et al., 2012). Our results are congruent with Shashi et al. (2018), who empirically confirmed that the performance improvement for each FCC member would enhance subsequent members' performance. Another interesting finding was that, when comparing the two mediators, our empirical results suggest that value addition exerts a stronger direct effect on FCCP than partners' performance. This could indicate the immediate and tangible benefits that value-adding activities can bring to a firm, directly impacting critical aspects of operations, such as cost, quality, and customer satisfaction, which are central to performance (Shashi et al., 2019). Partners' performance, while essential, may have a more extended and nuanced pathway to influence FCCP because it involves aligning and harmonizing activities across entities within the supply chain.

6.4 Practical Implications

This study's findings present several actionable insights for members of the FCC, particularly in Thailand. The data used in the analysis include a broad range of respondents with varying levels of experience and organizational roles, primarily in smaller, locally operating companies. This demographic landscape reflects Thailand's FCC sector, mainly comprising small- and medium-sized organizations.

The results indicate that investments in infrastructural components, such as technology and storage facilities, significantly influence the process of adding value to products. Given that many respondents work in small organizations and on a local or regional scale, it is important for these entities to focus on infrastructure. Upgrading technological capabilities, storage, and transport facilities can contribute greatly to enhancing product quality and reducing wastage. Small organizations in Thailand could collaborate to share the costs and benefits of such infrastructural improvements.

Moreover, a significant portion of informants had less than five years of experience, indicating a relatively young and less experienced workforce. Investing in training and development for this young workforce can yield useful dividends. While the direct impacts on overall cold chain performance are insignificant and not immediate, our study finds that a better infrastructure indirectly contributes to better cold chain performance through its effect on value addition. Given Thailand's strategic position in Southeast Asia and its agricultural heritage, there is a wealth of opportunity to position the country as a leader in cold chain logistics.

Furthermore, the integration of processes and coordination between stages of the cold chain has emerged as a substantial contributor to overall cold chain performance, the effectiveness of partnering entities, and the ability to add value to products. Networking and collaboration among these smaller entities can enable shared learning, streamlined operations, and joint strategies for market penetration. Particularly in the Thai context, fostering relationships between the chain's actors, from suppliers to retailers, is vital. In addition, our findings suggest that improvements at the partner level impact the entire chain's performance; indeed, in Thailand's context, where many businesses are small and locally focused, partnerships are especially crucial. Collaborative problem solving, joint ventures, or simply transparent and regular communication with partners can lead to noticeable improvements.

The research findings also suggest that the implementation of sustainability practices has a significant impact. Although the direct effect of such practices on overall cold chain performance is insignificant, adopting sustainability practices can enhance partners' performance and contribute to value addition. The expanding involvement of Thailand in international trade offers a promising prospect for promoting sustainability as a distinguishing characteristic. For most respondents who are relatively new to the industry, adopting and advocating for sustainable practices can be a long-term strategic advantage. Engaging in eco-friendly practices, sustainable procurement, and energy-efficient operations can set Thai companies apart in international markets where consumers are placing greater value on sustainability. Hence, firms should consider comprehensive training programs that incorporate sustainability, technology use, and logistics management.

In conclusion, in the burgeoning and competitive Thai FCC market, these insights indicate the leverage that can be gained from strategic focus areas. Emphasizing infrastructure, integration among stages of the cold chain, sustainability, staff training, and partner relationships could not only bolster individual firms but also may collectively advance Thailand's entire FCC sector toward better efficiency, profitability, and global standing.

6.5 Future Research Directions

Various prospects for further investigation have arisen upon careful examination of the current study's outcomes and constraints. These avenues can enhance, validate, or refine the FCCP model.

First, there is a need to improve the model; some relationships turned out to be insignificant, which contrasts with the existing literature. This discrepancy suggests the necessity for modifications to future research. One potential change could be to utilize a different dataset. The dataset used in the present study is relatively imbalanced and lacks sufficient representation of large organizations and respondents in managerial positions. Given that managerial personnel often possess broader insights into the functioning and strategy of their organizations, their perspectives could offer more comprehensive and strategic information. Therefore, to improve future research, it would be advantageous to include more participants from larger organizations and those in managerial positions. This refined dataset might yield disparate and potentially more robust insights, thereby enhancing the model's validity and reliability. Second, the discriminant validity in the current study, while passing the criteria, was not entirely satisfactory. Several indicators in the study exhibited high cross-loadings, although the differences were higher than the critical threshold of 0.1. Therefore, future research should consider refining these indicators. This could involve developing more precise indicators to mitigate these cross-loading issues and improve the model's discriminant validity.

Moreover, it may be beneficial to consider the incorporation of other variables into the FCCP model, which could augment the model's accuracy and provide a more comprehensive understanding of the subject matter. The indirect effects, in particular,

required further exploration, as the current study's findings revealed several indirect effects of various constructs on FCCP. Future research could probe these effects in more detail, thereby enriching the FCCP model's depth and complexity. Breaking down FCCP into several constructs based on performance aspects, such as economic performance, operation performance, and environmental performance, might provide more intriguing insights. This separation could enable a greater understanding of the factors that contribute to performance and help craft more targeted performance improvement.

Given the current global landscape, there is a growing emphasis on the importance of sustainability in various industries. This study, despite explicitly highlighting the significance of sustainability in the FCC, still underscores its importance. To advance our understanding of this topic, it is recommended that future research expand upon the existing model to encompass a broader range of sustainability aspects, which will undoubtedly contribute to the development of more environmentally conscious and sustainable practices within the food industry. This improvement could involve the development of new, more comprehensive measures of sustainability, which might provide a richer and more nuanced picture of how sustainability interfaces with FCCP. Furthermore, introducing constructs that capture sustainability practices as mediating variables could offer valuable insights. For instance, investigating how specific sustainability practices (e.g., sustainable procurement and sustainable design) mediate the relationship between sustainable orientation and performance could be an important contribution.

In conclusion, this study has opened a range of diverse and extensive possibilities for future research. These findings have potential implications for various fields and could lead to further exploration of related topics. Future studies could augment the current model through an improved and balanced dataset, refining the indicators used, delving deeper into indirect effects, disaggregating performance into various aspects, and expanding the model to incorporate a richer and more nuanced treatment of sustainability. Such efforts could contribute substantially to our understanding of FCCP and help to develop more effective strategies for improvement, particularly in an era when sustainability is becoming increasingly central to business operations and strategy.

CHAPTER 7

CONCLUSION

The objective of this dissertation was to construct and examine a framework that illustrates the effect of diverse performance factors on the overall performance of the food cold chain (FCCP model). This framework encompassed a comprehensive set of performance factors, including infrastructure, integration, sustainability orientation, value addition, and partners' performance.

Through analyses of the structural equation model (SEM), several insights into the effect of performance factors on overall FCCP were derived. A key observation in this study was the insignificant direct effect of infrastructure on FCCP, which contradicts the conventional belief that infrastructure is the backbone of the FCC. Instead, this study has demonstrated that the infrastructure's effects are more subtle and act significantly through a mediating effect of value addition. Consequently, this empirical evidence challenges the existing literature that often places significance on the direct role of infrastructure. Nevertheless, our findings on infrastructure's indirect effect aligned with the existing literature, which emphasized the role of value addition as an integral mechanism that enables infrastructure to influence overall performance.

The most noticeable finding of this dissertation is the important effect that chain integration has on FCCP. Our study illustrated that integration is not only a beneficial factor, but also appears to be a critical determinant of performance. The positive and strong direct relationships between integration and performance were both intuitive and robust, especially when mediated through value addition. Compared to other exogenous factors, integration undoubtedly has the most profound impact on performance.

In terms of sustainability orientation, it did not exert a direct significant effect. However, this factor demonstrated influence on the overall chain's performance through the mediating effect of value addition and partners' performance. The

explanatory power of sustainability orientation on overall performance was essentially non-existent, reinforcing the claim that this construct relied heavily on mediating factors. This result was incongruent with existing literature suggesting that a sustainability orientation facilitates sustainable practices, which affect the chain's performance.

This research also revealed the critical mediating role that value addition and partners' performance play in the FCC. In particular, value addition was revealed to be a vital mediator in the effects of both infrastructure and sustainability orientation on the FCCP. These findings highlight the significance of these constructs and the need for strategic focus. Considering these findings, this dissertation underlined the importance of moving beyond mere infrastructure enhancement toward fostering integration, nurturing partnerships, strategically adding value, and embedding sustainability in a way that is more deeply woven into the fabric of cold chain operations.

Upon reflecting on the findings of this study, it was evident that the utilization of data was imperative for influencing research outcomes. This investigation highlighted the importance of addressing imbalanced datasets, especially inadequate representation from larger organizations and managerial respondents. This shortcoming contributed to the model's inconsistency with the existing literature, emphasizing the need to refine future research. Specifically, subsequent studies should prioritize a more comprehensive and balanced dataset, including larger organizations and an increased proportion of managerial respondents, who may have more profound insights into organizational functioning and strategy. Another noteworthy lesson was the unsatisfactory discriminant validity in the current study, despite its meeting the established criteria. This was manifested in high cross-loadings among several indicators, which signaled a need for more precise measures in future research to mitigate such issues and enhance the model's discriminant validity.

The complexity of indirect effects on FCCP was also unveiled in this study, yet it was not thoroughly explored. Further research on these indirect relationships will be beneficial, as it could enrich the FCCP model's depth and complexity. In addition, another analytic possibility would be to take advantage of breaking down FCCP into distinct constructs, such as economic, operational, and environmental performance, and analyze them to gain more insight into how factors interact with different aspects of

performance, thereby facilitating the development of more targeted and effective improvement strategies.

In conclusion, this dissertation contributes to the existing body of knowledge by emphasizing the critical roles of infrastructure, integration, sustainability orientation, value addition, and partners' performance on the performance of the FCC. Our research findings also hold practical import for practitioners, suggesting a strategic emphasis on promoting integration, developing robust partnerships, enhancing value addition, and integrating meaningful sustainability measures into cold chain operations. Additionally, our study has laid the foundation for future investigations in this vital industry.



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BIOGRAPHY

Name-Surname

Mr.WARAT KAEWPIJIT

Academic Background

Bachelor of Science in Information and Communication Technology (First Class Honors)
Mahidol University, Faculty of Information and Communication Technology, 2013

Experience

Master of Business Administration
Purdue University, Krannert School of Management, 2016
Warat Kaewpijit is a dedicated Ph.D. candidate specializing in Operations Management at the esteemed National Institute of Development Administration (NIDA) Business School in Bangkok, Thailand. He earned his Master of Business Administration degree from Purdue University's Krannert School of Management, where he honed his expertise in Business Analytics, Supply Chain Management, and Operations Management.
In his professional journey, Warat has showcased exceptional leadership acumen. Serving as the Managing Director of Sahapattanapan Co., Ltd., an authorized HINO truck dealership, he adeptly oversees the Sales, Service, and Spare Parts departments while making substantial contributions to strategic planning and execution. Furthermore, his role as General Manager at Oraphun Group, a prominent logistics firm specializing in construction materials, demonstrates his proficiency in handling complex operational challenges.
Warat's current research pursuits are centered on Operations Management, with a distinct emphasis on Supply Chain Management and Cold Chain Management. His Ph.D. research, titled "Food Cold Chain Performance," underscores his unwavering commitment to enhancing supply chain efficiency. This research seamlessly amalgamates his extensive practical experience with his fervor for academic inquiry. For prospective collaborations or inquiries, please don't hesitate to contact him at warat.kae@stu.nida.ac.th.