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Warat Kaewpijit, Viput Ongsakul

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Effects of sustainability orientation, integration, and value addition on food cold chain performance: a Thai perspective

Warat Kaewpijit and Viput Ongsakul*

NIDA Business School,
National Institute of Development Administration (NIDA),
Bangkok, 10240, Thailand
Email: warat.kaewpijit@gmail.com
Email: vongsakul@nida.ac.th
*Corresponding author

Abstract: Due to increasing environmental concerns, sustainability has become a major research topic in the food cold chain (FCC). However, the relationship between sustainability, FCC integration, value addition, and FCC performance has remained relatively unexplored. Therefore, this paper aims to address this gap by proposing a conceptual model depicting these relationships and examining them through structural equation modelling (SEM). Our findings highlight the significant relationship between sustainability orientation, integration, value addition, and FCC performance. The empirical evidence suggests that sustainability orientation positively impacts FCC performance. Meanwhile, integration is proven to be the most influential factor, overshadowing others in its impact on FCC performance. In addition, value addition proved to be a significant mediator with its role in bridging the relationship between sustainability orientation and FCC performance. This research contributes to the existing body of knowledge by empirically illuminating the relationship between sustainability, FCC integration, and value addition in driving cold chain performance, offering novel insights for practitioners and policymakers in the FCC sector.

Keywords: food supply chain; FCC; food cold chain; food cold chain performance; sustainability; integration; value addition.

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Biographical notes: Warat Kaewpijit is a PhD candidate specialising in Operations Management at the esteemed National Institute of Development Administration (NIDA) Business School in Bangkok, Thailand. In his professional journey, he is serving as the Managing Director of Sahapattanapan Co., Ltd., an authorised HINO truck dealership. Furthermore, he also holds the position of General Manager at Oraphun Group, a prominent logistics firm specialising in construction materials. His current research pursuit is centred on operations management, with a distinct emphasis on supply chain management and cold chain management. His PhD research titled 'Food Cold Chain Performance', underscores his unwavering commitment to enhancing supply chain efficiency.

Viput Ongsakul is a former Dean at NIDA Business School, National Institute of Development Administration (NIDA), Thailand. He currently serves as Commissioner of the Securities and Exchange Commission (SEC). Also, he is an advisor affiliate at the Center for Competitiveness at the University of Fribourg, Switzerland. He has volunteered to serve as a chair and member for both AACSB and EFMD accreditation peer review teams for many schools in China, India, Thailand, and Malaysia. Through his teaching, consulting, and research in the fields of competitiveness, business policy, sustainability, competitive strategy, and operations, he has engaged in many consulting works for both public and private agencies.

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1 Introduction

The food cold chain (FCC) is recognised as essential to the food industry. It plays a vital role in preserving the quality and freshness of various perishable products. Despite its role in controlling product integrity, the environmental impact of its activities remains a significant concern. Notably, the FCC contributes a staggering 3.3 billion tons of CO_2 emissions annually from food waste, energy consumption, and greenhouse gas emissions caused by refrigerants. This highlights the urgent need for sustainable solutions that minimise the environmental impact of food waste and decrease the food industry's carbon footprint (Bozorgi, 2016; FAO, 2019; James and James, 2010). As we progress towards a future where sustainable supply chain management (SCM) is increasingly valued for its positive impact on the environment, society, and financial outcomes, it is becoming increasingly evident that integrating sustainability into the FCC is both imperative and praiseworthy.

The FCC is vital to people's well-being globally. It plays a major role in satisfying the rapidly growing food demand that has resulted from the increasing global population. As the world's population is projected to reach a staggering 9.7 billion in the next two decades, the surge in food demand will place immense pressure on the FCC, as an additional 2 billion individuals will require sustenance (UN DESA, 2019). It can be said that the FCC promotes the concept of a 'global food village' with its roles in preserving the integrity of food products and distributing them globally (Ovca and Jevšnik, 2009; Cerchione et al., 2018b). Millions of tons of food circulate in the FCC around the world on a daily basis. However, a significant amount of the food produced, roughly 1.3 billion tons, is lost/wasted along the chain annually for various reasons (FAO, 2011). In addition to the loss of precious food resources, food waste also contributes to global greenhouse gas emissions. In addition, FCC activities have a large impact on the environment since the temperature control process at all points in the chain requires energy and chemicals that can harm the environment. Researchers have estimated that 1% of global carbon emissions are attributable to cold chain activities (Bozorgi, 2016; James and James, 2010). This urgency is amplified by the escalating global food demand, necessitating that the FCC become more efficient and sustainable.

Sustainable SCM attracts both practitioners and researchers, as it creates substantial benefits not only to the environment but also to social and financial gains for firms. Related practices contribute to environmental sustainability, enhance competitive advantage and, ultimately, the chain's performance (Babagolzadeh et al., 2020). For instance, optimal resource planning can lead to higher efficiency for firms, resulting in higher financial performance (Rao and Holt, 2005; Beske et al., 2014). While the FCC significantly impacts well-being and the environment, research on its sustainability remains limited, despite being one of the field's major research areas (Cerchione et al., 2018b). This may be due to the fact that researchers, in the early days, focused mainly on the benefits of the FCC in sustaining product shelf life and maintaining product quality. However, with rising awareness of the need to preserve the environment, interest has shifted to the impact of the FCC on the environment and to strategies for reducing energy consumption, carbon emissions, and food loss/waste (James and James, 2010; Bozorgi et al., 2014; Saif and Elhedhli, 2016).

Studies have demonstrated that a sustainable FCC cannot be achieved by a single entity. Instead, it requires collaboration among members of the FCC since they significantly influence each other in various dimensions (Shashi et al., 2017, 2018a; Ongsakul et al., 2019). Several pieces of literature have proven that FCC integration plays a crucial role in implementing any changes in the supply chain, including sustainable practices. For instance, collaboration between producer and distributor could reduce food waste by optimising quantity and freshness-keeping efforts, eventually leading to superior FCC performance (Cai et al., 2010).

The amalgamation of sustainability orientation and integration lies in the potential for both value addition and enhanced performance. The intersection of these two concepts also sets the stage for substantial value addition: whether by extending the shelf life of products, ensuring higher nutritional value, or guaranteeing ethically sourced ingredients, value addition becomes a natural outcome of a well-integrated, sustainability-oriented chain. Hence, it can be said that sustainability can enhance a cold chain's performance via value addition. In addition, value addition itself is proven to directly impact a firm's market, customer, and financial performance, thus becoming an indispensable requirement for a firm's success (Martinez, 2014; Shashi et al., 2017; Aworh, 2015). Studies have shown that many customers are willing to pay more for higher value-added products (Servaes and Tamayo, 2013). Kumar et al. (2013) also highlighted that customer value is positively related to customer satisfaction and loyalty.

Given the intricate interplay and relationships among the various factors influencing the FCC, coupled with the complexities inherent in understanding their synergies, our research endeavours to comprehensively address the following pivotal question:

RQ: How do sustainability orientation and integration within the FCC influence its performance, both directly and through value addition?

Thailand, often hailed as the 'Kitchen of the World', is a significant player in the global agricultural landscape. As a top exporter of various agricultural products, from rice to fruits and seafood, the nation naturally emphasises the vital role of an efficient cold chain system. Its tropical climate, which poses unique preservation challenges, further magnifies the importance of a resilient FCC. Economically, the agricultural domain significantly buttresses Thailand's GDP, cementing the indispensability of maintaining food product integrity for both domestic consumption and global markets. Concurrently,

Thailand's stride towards sustainability, aligned with its national agenda and global sustainability benchmarks, spotlights the need for integrating green practices within its FCC. The nation's burgeoning urbanisation also underscores the increased demand for a robust cold chain catering to urban consumers' year-round fresh produce requirements. Given these multifaceted dimensions, Thailand offers a rich context for a nuanced exploration of FCC dynamics, fortifying its selection as the current study's focal point.

Revolving around the proposed research question and our focal country, the objectives of the study are manifold. First, it examines the effect of sustainability orientation and integration on value addition in the FCC in Thailand. Second, it aims to explain how these factors influence the overall performance of the FCC.

The remainder of the paper is organised as follows. Section 2 gives an extensive overview of sustainability and the performance of FCCs in the literature. Following that, Section 3 introduces a conceptual model that explains the correlation between food sustainability orientation, integration, value addition, and FCC performance. The research methodology employed is described in Section 4. The analytical results are presented in Section 5 and discussed in Section 6. Section 7 discusses the research limitations and future research opportunities. Finally, Section 8 summarises the primary discoveries and contributions of this work.

2 Literature review

2.1 Literature on the FCC

For decades, the area of SCM has been a major research field for both researchers and practitioners. Maestrini et al. (2017) categorised studies in the field of SCM into eight areas according to journal disciplinary area and related impact factors, namely (1) accounting, (2) sector 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. Due to growing environmental concerns, sustainability in SCM has been attracting more attention in recent years. Carter and Rogers (2008) defined the concept of sustainability as "the strategic, transparent integration and achievement of an organisation's social, environmental, and economic goals in the systemic coordination of critical inter-organisational business processes for improving the long-term financial performance of the individual and its supply chain". The majority of research in the area of sustainability revolves around how sustainability could affect supply chain performance. Several authors have confirmed that there exists a positive relationship between sustainability and supply chain performance. However, sustainability knowledge remains lacking in the field of FCC. Despite being a major research area, fewer than 30 studies on FCC sustainability have been published in the past two decades (Cerchione et al., 2018b). Studies that investigate the effects of sustainability, integration, value addition, and FCC performance are even more scarce.

Rodrigue et al. (2016) 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. Briefly, the cold chain can be considered a subcategory of the traditional supply chain with an additional temperature control feature for perishable products (Shabani et al., 2015).

Hence, research on sustainability in SCM still holds, but only to a certain degree – sustainability issues in the FCC require attention as those additional features, such as temperature control requirements and the perishable nature of products, cause a more severe impact on the environment. Like that on traditional supply chains, the majority of research revolves around performance improvement, while sustainability issues are considered secondary objectives (Cerchione et al., 2018b, Shukla and Jharkharia, 2013).

To address concerns about the environment, researchers have been exploring the impact of the supply chain from both economic and environmental perspectives (Ross Morrow et al., 2010; Absi et al., 2013; Bastani et al., 2012; Bazan et al., 2015a, 2015b, Benjaafar et al., 2013; Bonney and Jaber, 2011; Bouchery et al., 2012). Diving deeper into the intricacies of sustainability within the FCC, Osman et al. (2023) identified eight primary challenges confronting the FCC industry. Notably among these are sustainability concerns, specifically the escalating issues of food waste and losses, as well as the substantial energy consumption. Concurrently, sustainability practices have become major strategic business initiatives for many firms, since they contribute to improvement in social performance and the competitive advantage of the supply chain with their roles in generating new revenue streams and increasing customer satisfaction (Klassen and Vereecke, 2012; Rao and Holt, 2005; Mincer, 2008). Deepening this perspective, Sharma et al. (2023) introduced the concept of Green, Resilient, Agile, and Sustainable (GRAS) supply chains, particularly in the Indian fresh food sector. Their findings emphasised the crucial influence of organisational culture and environmental certifications on sustainability outcomes. Furthermore, Pratyameteetham and Atthirawong (2017) highlighted the positive effect of members' green practices on the hotel industry's performance. Currently, most studies are related to the impact of the FCC on the environment, especially on carbon emissions from FCC activities. Bozorgi (2016) pointed out that the FCC contributes to a significant proportion of global carbon emissions and proposed an inventory model with the inclusion of cost and carbon emissions. Similarly, Meneghetti and Monti (2015) developed an optimisation model for the sustainable design of refrigerated automated warehouses.

Since achieving FCC sustainability requires collaboration among members of the chain, FCC integration is considered a crucial factor in the process. This assertion is further supported by the technology, organisation, and environment (TOE) framework, which explores how technological, organisational, and environmental contexts shape the adoption and efficient application of innovations within organisation. In this vein, Gani and Takahashi (2022) have underscored that all components within the framework demonstrate a strong positive relationship with quality management systems (QMS), which in turn positively influences supply chain performance. On the importance of collaboration, Lewis et al. (2015) stated that collaboration is required in the implementation of a sustainable supply chain. Similarly, Adamashvili et al. (2020) suggested that collaboration among farmers plays a vital role in enhancing sustainability in the agriculture sector. Likewise, Shashi et al. (2018b) highlighted that sustainable orientation and integration have a positive relationship with the environmental and economic performance of small and medium-sized enterprises (SMEs). Not only assisting in implementing sustainable practices, supply chain integration is essential in improving competitive advantage, supply chain operational performance, and financial performance (Sharma and Pai, 2015; Jie et al., 2013; Chang et al., 2016). Chen et al. (2017) pointed out that interfirm alliances are crucial in firms' transformations toward sustainability.

Optimal utilisation of material, energy, and workforce can be achieved through a co-design manufacturing system (Martin and D'Acunto, 2003). FCC integration can also facilitate value addition to the supply chain. Apart from aiding the value-adding process by enabling sustainability practice, collaboration among members assists in information sharing, which allows the FCC to understand and respond to customers' needs (Cai et al., 2010; Fabbe-Costes and Jahre, 2008; Koufteros et al., 2005).

Value addition is considered a crucial part of any supply chain, including the FCC. The term was introduced in the 1980s, indicating an increase in product value as perceived by customers, and researchers have been exploring the area since then. Liu and Lian (2009) defined value addition as 'a systematic integration of supply chain processes in which the worth of the products starts increasing from the production point and becomes higher at the consumption point in order to deliver maximum value to the customer in profitable manners'. Similarly, Aworh (2015) stated that value addition consists of 'any act to enhance the shelf life of perishable products, lessen the rate of postharvest losses, and boost its demand in the market, which improve the firm's profitability'. It can be said that value addition is 'a process of transforming raw farm products into more variety and value-oriented processed products' (Paraman et al., 2015). Highlighting its significance, Mahajan et al. (2015) pointed out that inadequate investment in value addition processes, such as processing machinery, grading and packaging, and cold storage systems, can transform it into a significant performance constraint, instead of enhancing it. According to Trienekens (2011), firms are now aware of the importance of value-addition practices – not only their own but also those of other supply chain members, since delivering exceptional value to customers is crucial in today's competitive market. Incorporating sustainability practices can also lead to value-added products. Research has shown that customers behave rationally and comparing the product price with its worth, hence implying that they are willing to pay more for value-added products, which includes value addition from sustainable practices (Servaes and Tamayo, 2013; Manning, 2015). Hsu et al. (2022) reported a positive relationship between value added and sustainability. They also found that spillover effects can benefit other firms in the supply chain. Nonetheless, study of value addition is still considered lacking in the context of the FCC (Shashi et al., 2017).

2.2 The concept of shared value and sustainable FCC

The convergence of value creation and sustainability introduces an evocative notion: shared value. Kramer and Porter (2011) pioneered this concept, presenting it as a renewed vision of capitalism. They emphasised its formidable potential not only as a catalyst for economic growth but also as a bridge reconciling business interests with societal well-being. They articulated that businesses do not merely operate within societal confines but can deeply intertwine with and significantly contribute to societal health and prosperity. They further defined shared value as policies and operating practices that augment a company's competitiveness while concurrently advancing the economic and social conditions in the communities they serve. While Porter and Kramer set the foundational understanding of shared value, subsequent researchers have critically analysed its practicality and clarity.

Diving deeper, Dembek et al. (2016) launched a critical investigation into shared value. A central finding from their exploration asserts: 'The current conceptualisation of shared value is vague and lacks empirical grounding. It overlaps with many other related

concepts and lacks a solid foundation for measurement'. Such a revelation indicates the challenges surrounding shared value's burgeoning popularity. While the concept has been recognised and embraced, it often finds itself caught in the murky waters of conceptual ambiguity, sometimes acting as a buzzword without substantive underpinning. This complexity makes it challenging for businesses and researchers to operationalise and measure it. Despite this critique, they noted its potential. With proper implementation, the concept of shared value has the potential to guide organisations toward aligning their business practices with broader societal impacts, thereby generating comprehensive value.

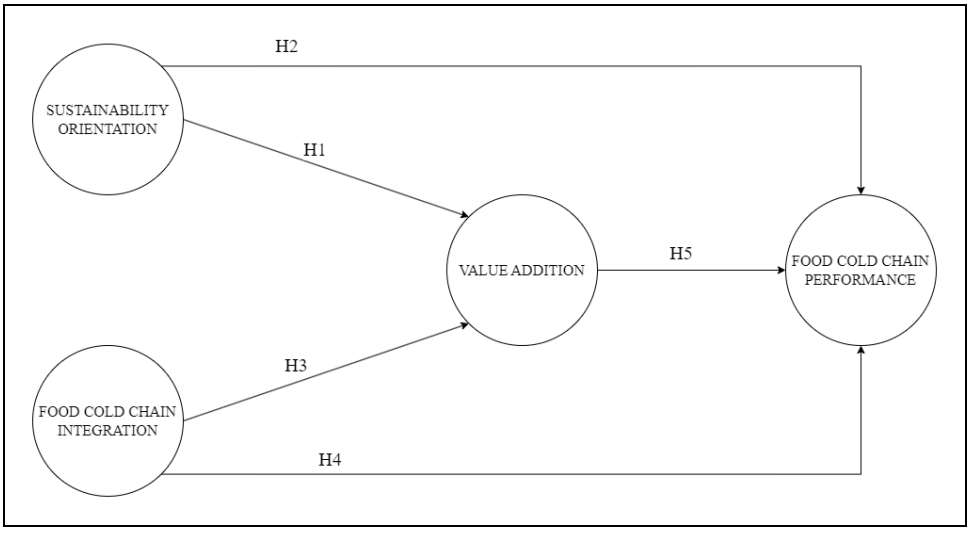
With the lens refocused on the FCC, it is evident that the alignment of shared value principles is not merely theoretical but holds real-world implications. Drawing on insights from Stubbs and Cocklin (2008) and Kramer and Porter (2011), Bocken et al. (2014) underscored the potential of business model redesign. They suggested that with strategic modifications, mainstream businesses can integrate sustainability more inherently into their operations. This integration can be foundational and entrenched for emerging start-ups from the beginning of their operational journey. These innovative business models, resonating with shared value ideals, pave the path for a systematic and sustained development of business cases centred on sustainability, a notion supported by Schaltegger et al. (2012). This highlights the importance of the triple bottom line approach, which encompasses environmental stewardship, societal benefit, and economic growth. Bocken et al. (2014) further posited that the FCC should not be perceived solely as a mechanism for product preservation or temperature regulation. Instead, it represents a broad spectrum of opportunities. Each stage, from production to consumption, presents avenues to pursue shared societal and economic objectives. This perspective includes strategies such as optimising energy efficiency, converting waste into valuable assets, transitioning to renewable sources, and realigning business goals to better align with overarching societal and environmental objectives. Building upon these insights from the literature, the next section delves into the development of the conceptual model providing a structured framework for shared value in the FCC.

3 Conceptual model development

Based on an extensive literature review, we propose a conceptual model that depicts the relationship between sustainability orientation, FCC integration, value addition, and FCC performance (see Figure 1).

In recent decades, the significance of sustainability orientation becomes evident as researchers and practitioners have been focusing on incorporating sustainability practices into supply chain operations and models (Hassini et al., 2012). By embracing practices like minimising carbon emissions and streamlining inventory, organisations can improve their ecological footprint and strengthen their competitiveness and overall performance (Babagolzadeh et al., 2020). Furthermore, findings by Hsu et al. (2022) also highlight the symbiotic relationship between sustainability orientation and value addition, in which ultimately impact the overall chain performance. With these insights, we perceive sustainability orientation as a fundamental construct in our model, given its profound influences on value addition and cold chain performance.

Figure 1 Conceptual model



Building on the intricacies of the FCC, the importance of both internal and external integration becomes paramount. As empirically proven by Cerchione et al. (2018a), integration not only affects sustainable practices but also has a profound impact on performance, especially within the small and medium-sized enterprises context. Several pieces of literature also highlight integration vital influence on both operational performance and financial performance of the chain (Chang et al., 2016; Jie et al., 2013; Sharma and Pai, 2015). Efficient collaboration among chain members fosters seamless information and resource sharing, boosting efficiency and enhancing decision-making capabilities. This integration-driven approach, therefore, becomes a linchpin in enhancing the value addition process. In light of these dynamics, we firmly believe that genuine sustainability and peak performance are unattainable without a solid foundation of integration in the framework.

Diving deeper into the chain's functionality, we turn our attention to the significant aspect of value addition which stands out as a cornerstone in the construct of the FCC. It plays a pivotal role in dictating chain efficiency, product quality, and strategic competitiveness. Hence, multiple studies have confirmed to its fundamental influence in driving business success by significantly impacting a firm's performance (Aworh, 2015; Martinez, 2014; Shashi et al., 2017). Interestingly, sustainability orientation can foster processes like sustainable procurement or sustainable design, both integral examples of value addition. When these are executed with finesse, they can render monumental benefits across the cold chain (Cerchione et al., 2018a). In this light, value addition emerges not just as a bridge, but as a catalyst, driving product improvement, ensuring cost-effectiveness, and facilitating seamless operations. Therefore, it was imperative to integrate this construct into our model as sustainability and overall performance are intrinsically linked to value addition processes.

In the upcoming section, we further delve into the hypotheses that underpin the relationships between these constructs.

4 Hypotheses

Building upon the conceptual model proposed in the prior section, we formulate the hypotheses that depict the relationship among constructs. These hypotheses are grounded in academic literature and seek to explore how sustainability orientation and FCC integration directly and indirectly, via value addition, influence FCC performance.

4.1 Sustainable orientation

In recent years, incorporating sustainability into supply chain operations and models has been a major focus of both researchers and practitioners (Hassini et al., 2012). Sustainability practices not only benefit firms individually but also contribute to the improvement of supply chain performance as a whole, which can lead to competitiveness and economic performance (Klassen and Vereecke, 2012; Rao and Holt, 2005; Mani et al., 2018; Kleindorfer et al., 2005). Therefore, firms are now seeking to gain a competitive advantage through improvement of their sustainability practices. This strategic shift towards sustainability is rooted in an understanding that it does not just advocate for environmental responsibility but also brings tangible economic benefits, opens up new revenue channels, and enhances customer satisfaction (Mincer, 2008). Adopting such strategies across various supply chain processes culminates in an integrated sustainable supply chain that offers a competitive edge (Fraj-Andrés et al., 2009). Literature suggests that sustainability adoption not only elevates a firm's own performance but also acts as a catalyst, optimising the overall effectiveness and competitive stature of the entire supply chain (Pagell and Wu, 2009; Hollos et al., 2012). For instance, sustainability practices such as new product design, improved production processes, or other chain activities can significantly impact several aspects of the supply chain (Klewitz and Hansen, 2014; Aikenhead et al., 2015). These innovative activities provide substantial value to the chain. Hsu et al. (2022) investigated the effect of corporate social responsibility (CSR) on value added in the supply chain and confirmed a positive relationship between them. Their study also showed that the benefit of CSR was extended to other members of the chain.

In addition to improving value addition along the chain, several pieces of literature suggest that sustainability orientation also influences the overall performance of the chain. Babagolzadeh et al. (2020) proposed an optimisation model incorporating carbon emissions into replenishment policies and transportation schedules, thus minimising operational and emissions costs. Similarly, Bozorgi (2016) proposed an inventory optimisation model that determines inventory level while minimising either cost or carbon-equivalent emissions. In addition, sustainability orientation significantly impacts the value addition of the product. In an effort to promote the concept of sustainability, the idea of the circular supply chain was proposed. It is focused both on the production of primary products and on generating social, economic, and environmental value from byproducts or even waste (Batista et al., 2018). The above discussion results in our claim that:

H1: Sustainability orientation positively affects value addition.

H2: Sustainability orientation positively affects food cold chain performance.

4.2 Food cold chain integration

The literature has highlighted that integration is crucial in supply chain performance improvement, both operational and economical, which leads to superior competitive advantages (Sharma and Pai, 2015; Jie et al., 2013; Chang et al., 2016). It provides firms an opportunity to improve their operations through collaboration among members in aspects such as information sharing, product design, or other resource sharing (Vijayasarathy, 2010). Through sharing information, members of the chain can have a better understanding of customers' needs and respond to them efficiently (Cai et al., 2010; Fabbe-Costes and Jahre, 2008; Koufteros et al., 2005). Researchers have also confirmed that resource sharing among members can solve many inefficiencies, such as in inventory, cost, and wastage, and ultimately improve the performance of the FCC (García-Arca et al., 2014; Flynn et al., 2010). Likewise, integration among members of the chain was proven to be crucial in improving a firm's ability to expand its market and optimise its operations (Zsidisin and Siferd, 2001; Carter, 2004; Limoubpratum et al., 2015). Bai and Sarkis (2010) elucidate the interconnection between sustainability attributes and supplier selection, emphasising the role of integration in supply chain decisions. Through their innovative application of grey system and rough set theories, they underscore the intricate relationship between sustainability and supply chain practices. Their research highlights the indispensable linkage between sustainability and supply chain integration, offering a comprehensive methodology for organisations to foster both simultaneously.

Integration in the FCC also positively influences the value-addition process. Integration helps improve operating performance and customer satisfaction, which could indirectly lead to improvements in product quality and customer service (Stank et al., 2001). Moreover, integration allows firms to have original ideas to better serve customers, thus generating customer value advantage (Cagliano et al., 2006). It is apparent that integration is vital in the value-addition process of the FCC, as Shashi et al. (2017) proved that the value addition of upstream members can significantly affect that of downstream members. Based on the above discussion, we may claim that:

H3: Food cold chain integration positively affects value addition.

H4: Food cold chain integration positively affects food cold chain performance.

4.3 Value addition

Value addition has a significant impact on firm performance. Several pieces of literature have highlighted that value-addition practices can improve various aspects of the supply chain, such as efficiency, product quality, product availability, customer service, customer satisfaction, waste management, or even superior competitive advantage in the market (Maestre et al., 2017; Aworh, 2015; Chang et al., 2016; Martinez, 2014; Joshi et al., 2009). Kumar et al. (2013) expounded that the essence of customer value reverberates in facets like customer satisfaction and loyalty. This sentiment was echoed by Shashi et al. (2019), who attested to the symbiotic relationship between value addition and overarching firm performance. The implications of this are especially salient in the realm of FCCs, where value-added interventions, ranging from optimal temperature management to sustainability measures, preserve the integrity of food products, thus amplifying their quality. This, in turn, acts as a linchpin for bolstered customer

satisfaction, leading to iterative purchases and surging sales (Aung and Chang, 2014). In addition, value-adding through various sustainability practices, the so-called 'going green', can have a positive impact on firm image and increase customer value, thus increasing the demand for products (Ageron et al., 2012; Padilla-Zakour, 2004; Hsu et al., 2022). Based on the above discussion, we hypothesised that:

H5: Value addition positively affects food cold chain performance.

5 Methodology

This study employed a quantitative methodology to investigate the relationship between sustainability orientation, FCC integration, value addition, and FCC performance. To comprehensively investigate these interconnections, a structured survey was conducted with members of the FCC in Thailand. Partial least squares structural equation modelling (PLS-SEM) was chosen as the primary analytical tool for its proven suitability and advantages.

5.1 Data collection

Data collection consisted of two stages. The first stage was the questionnaire development. An initial version of the questionnaire was created based on an extensive review of relevant literature. The questionnaire was then shared with practitioners and experts for feedback and revisions. The finalised questionnaire utilised a 5-point Likert scale for its simplicity, efficiency, and proven effectiveness in social science research. In the second stage, the finalised questionnaire was distributed in Thailand in 2023 through a web-based platform and a snowball sampling technique to ensure participants were in the FCC industry.

5.2 Measures

Measurements for variables in the model were initially derived from an extensive literature review and then refined according to expert opinion.

Sustainability orientation underlines the significance businesses place in promoting sustainability within the FCC, addressing environmental issues at the forefront. Key metrics to measure this construct have been distilled from the work of Kuckertz and Wagner (2010), which scholars have recognised and utilised in most studies regarding sustainability orientation. This resulted in a six-item scale to measure sustainability orientation, conceptualising it in terms of social responsibility and environmental protection.

Integration is a crucial aspect of any supply chain and can be divided into internal and external categories. The internal aspect focuses on the consistency of activities within the organisation. In contrast, the external aspect considers the collaboration between an organisation and its external partners, such as suppliers and customers. Primarily, the measurement for integration was derived from the work of Cerchione et al. (2018a), which involves both internal and external integration. In addition, we relied on a study by Basnet (2013) to refine the measurement for internal integration. Consequently, 28

measures were derived, divided into 13 measures for internal integration and 15 for external integration, respectively.

In order to measure the value addition within the model, we have drawn insight from the work of Shashi et al. (2017). A total of 20 measures have been identified for measuring value addition. Finally, we relied on Aramyan et al. (2007) and Fattahi et al. (2013) to develop FCC performance measurements. A total of 24 performance measurements have been derived and subsequently categorised into four dimensions: efficiency, flexibility, responsiveness, and food quality. This categorisation serves to enhance the understanding and analysis of the derived measurements.

6 Results

A total of 126 valid responses were collected through an online questionnaire with snowball sampling in Thailand's food industry, which was a sufficient sample size for analysing the model (Hair et al., 2016). In the study's demographic profile, the most prominent group of respondents had less than a year's experience in the FCC sector, accounting for 39.7%, closely followed by those with 1–5 years at 38.9%. Respondents with more than a decade of experience were the least represented, making up only 5.6%. When looking at the size of the organisations, a majority operated at a small scale (with less than 50 employees or annual revenue below 30 million Baht), comprising 53.2% of the respondents, while large organisations (with more than 500 employees or annual revenue above 300 million Baht) accounted for just 10.3%. In terms of operation location, a significant 66.7% of businesses operated at a local or regional level, with only a minor fraction (9.5%) having international operations. Delving into the roles of these organisations within the cold chain, food processors were predominant at 31%, followed closely by retailers at 29.4%. Lastly, for the respondent's individual roles, those in operations or production were most represented at 37.3%, with management or executive-level professionals making up 27%. Table 1 details respondents' demographic profiles.

Several measures were examined to ensure the reliability and validity of the model. First, the model analysis shows multiple indicators with variance inflation factors (VIFs) greater than 10, signalling severe multicollinearity problems (Mason and Perreault, 1991). To address this, indicators were systematically removed, starting with those exhibiting the highest VIF values. During this stepwise elimination process, careful consideration was given to ensure that the removal of any indicator did not compromise the integrity of the construct. This procedure continued until no indicators with a VIF value greater than 10 remained in the model (see Table 2). Second, Cronbach's alpha and composite reliability (CR) were used to determine the construct reliability of the model. Cronbach's alpha and CR for all constructs reach the thresholds of 0.7 and 0.6, respectively (Nunnally and Bernstein, 1994; Bagozzi and Yi, 1988). In order to assess convergent validity, we thoroughly analysed the average variance extracted (AVE) of the various components in our model. The AVE values we obtained are as follows: sustainability orientation at 0.693, FCC integration at 0.707, value addition at 0.765, and FCC performance at 0.722. As all these values exceed the 0.5 threshold, we can confidently state that our model's construct validity is adequate (see Table 3).

Table 1 Respondent demographic profile

Demographic profile	*Frequency*	*Percentage*
Experience		
Less than 1 year	50	39.7%
1–5 years	49	38.9%
6–10 years	20	15.9%
More than 10 years	7	5.6%
Organisation size		
Large	13	10.3%
Medium	46	36.5%
Small	67	53.2%
Operation location		
International	12	9.5%
National	30	23.8%
Local/Regional	84	66.7%
Organisation role		
Food Supplier	27	21.4%
Food Processor	39	31.0%
Distributor	12	9.5%
Retailer	37	29.4%
Others	11	8.7%
Respondent role		
Management/Executive Level	34	27.0%
Operations/Production	47	37.3%
Quality Assurance/Control	17	13.5%
Supply Chain/Logistics	9	7.1%
Other	19	15.1%
Grand total	226	100%

The discriminant validity of the model was also assessed using cross-loadings and the Fornell–Larcker criterion. The results show no indicators with loadings lower than 0.4, indicating that the model validity is ensured (Stevens, 2012) (see Table 4). However, we initially experienced a problem with high cross-loadings for several indicators. These indicators were systematically removed from the model, while others had to be retained according to the literature. Nevertheless, the final results show that the Fornell–Larcker criterion was met, as each construct's extracted variance was greater than the squared correlation of that construct with other constructs (Fornell and Larcker, 1981) (see Table 5). Therefore, we can confirm the discriminant validity of the model.

Table 2 Model VIFs

Sustainability orientation	*VIF*	*FCC integration*	*VIF*	*Value addition*	*VIF*	*FCC performance*	*VIF*
SO1	1.963	IN2	2.166	VA4	3.424	FCCP4	2.678
SO2	2.386	IN13	2.492	VA5	3.68	FCCP6	3.087
SO3	2.456	IN14	2.696	VA8	3.392	FCCP9	2.983
SO4	4.266	IN15	3.828	VA12	3.303	FCCP10	3.124
SO5	3.163	IN18	2.964	VA15	3.548	FCCP11	3.143
SO6	4.586	IN20	4.703	VA17	4.256	FCCP14	3.679
		IN21	3.904	VA18	4.646	FCCP15	3.907
		IN23	3.975	VA19	3.545	FCCP16	3.807
		IN24	4.476			FCCP17	2.741
		IN25	4.911			FCCP19	3.204
		IN27	3.051				

Table 3 Construct reliability and validity

	Cronbach's Alpha	*Composite reliability*	*Average variance extracted*
FCC integration	0.958	0.964	0.707
FCC performance	0.957	0.963	0.722
Sustainability orientation	0.910	0.931	0.693
Value ADDITION	0.956	0.963	0.765

Table 4 Outer loadings

Sustainability orientation	*Loadings*	*FCC integration*	*Loadings*	*Value addition*	*Loadings*	*FCC performance*	*Loadings*
SO1	0.741	IN2	0.759	VA4	0.855	FCCP10	0.856
SO2	0.81	IN13	0.797	VA5	0.864	FCCP11	0.852
SO3	0.837	IN14	0.807	VA8	0.871	FCCP14	0.871
SO4	0.899	IN15	0.864	VA12	0.865	FCCP15	0.863
SO5	0.82	IN18	0.823	VA15	0.864	FCCP16	0.865
SO6	0.879	IN20	0.88	VA17	0.901	FCCP17	0.823
		IN21	0.873	VA18	0.904	FCCP19	0.855
		IN23	0.872	VA19	0.873	FCCP4	0.826
		IN24	0.861			FCCP6	0.852
		IN25	0.88			FCCP9	0.833
		IN27	0.822				

Table 5 Fornell–Larcker criterion

	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

According to Falk and Miller (1992), the R-squared values of latent variables were used to measure the relative predictive power of the model. They indicate what measure our model explains the variance of a construct. The model reported R-square values of 0.735 and 0.79 for value addition and FCC performance, respectively (see Table 6). The results were above the threshold of 0.1 and high enough to conclude that the model has relatively high prediction power.

Table 6 Construct R-square

	R-Square	*R-Square adjusted*
FCC performance	0.776	0.771
Value addition	0.739	0.735

The results of the hypotheses testing are shown in Figure 2. The path coefficients (direct, indirect, and total effect) and the critical t-value for each hypothesis are presented in Table 7. The results provide support for all five proposed hypotheses. Hypothesis 1, which stated that sustainability orientation positively impacts value addition, was supported (total $\beta = 0.285$, $t = 3.300$, $p < 0.001$). Analysis results also supported Hypothesis 2, which claimed that sustainability orientation positively impacts FCC performance (total $\beta = 0.243$, $t = 3.107$, $p < 0.002$). Hypothesis 3, which asserted that FCC integration positively impacts value addition, was confirmed (total $\beta = 0.634$, $t = 7.521$, $p < 0.001$). Likewise, Hypothesis 4, which suggested that FCC integration positively impacts FCC performance, was supported (total $\beta = 0.662$, $t = 9.624$, $p < 0.001$). Finally, the result also confirms Hypothesis 5, which posited that value addition positively impacts FCC performance (total $\beta = 0.443$, $t = 4.983$, $p < 0.001$).

Diving deeper into our results, the standardised coefficients not only indicate the strength of relationships but also provide comparative insights. The notably highest coefficient for FCC integration compared to others emphasises its dominant role in determining the FCC performance. In addition, our analysis brings forth intriguing insights into the relationship between sustainability orientation and FCC performance. While the direct relationship between them appears small and insignificant, the indirect relationship, mediated through value addition, is more robust and is statistically significant. These findings suggest that sustainability orientation primarily influences FCC performance through mediating variables rather than exerting a direct effect. Altogether, the total effect of sustainability orientation on FCC performance emerges as significant, highlighting the intricate relationship between these variables. These insights pave the way for an in-depth exploration of the role of sustainability orientation and its far-reaching consequences within the FCC domain. In the following discussion section,

we further delve into the implications of these relationships, offering both theoretical insights and pragmatic strategies for industry practitioners.

Figure 2 PLS-SEM results (see online version for colours)

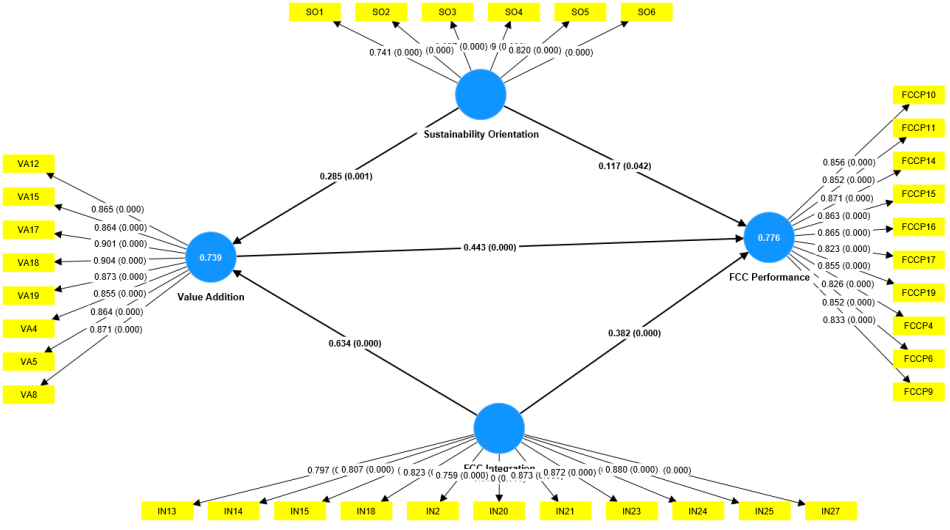


Table 7 Hypotheses testing results

		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	<0.001	Supported
H4	FCC Integration → FCC Performance	0.382	0.281	0.662	9.624	<0.001	Supported
H5	Value Addition → FCC Performance	0.443	0.000	0.443	4.983	<0.001	Supported

7 Discussion

The empirical evidence suggests that sustainability orientation enhances value addition. However, its direct influence on FCC performance appears less significant than suggested in prior research. This unexpected outcome can potentially be attributed to the characteristics of our sample population. Delving deeper into the respondent demographics revealed a predominance of small to medium-sized firms. Given their scale and priorities, such businesses may be less attuned to the long-term benefits of

sustainability, focusing instead on immediate operational needs. Their limited orientation towards sustainability may lead to underestimating how sustainability practices can bolster operations and financial health. Nevertheless, it is essential to highlight that despite its direct effects, sustainability orientation still exerts significant influences on performance, particularly through the mediation of value addition. This result is in congruence with an empirical study by Cerchione et al. (2018a) suggesting that sustainability orientation's impact on performance requires the mediating role of other factors, such as sustainable practices. Thus, while the orientation towards sustainability is foundational, actual practice and implementation are where tangible benefits are acquired.

Among the constructs studied, integration emerges as the most potent, receiving substantial empirical support. Aligning with prior studies such as those by Chang et al. (2016) and Jie et al. (2013), the pivotal role of integration in achieving competitive advantage and superior operational and financial performance is underscored. Notably, the total impact of integration on FCC performance surpasses all other factors, making it paramount in the discourse. Furthermore, the findings illustrate that integration has a strong direct effect on value addition, even more so than sustainability orientation. This distinction reinforces the idea that while sustainability is crucial, integration within the cold chain offers immediate, tangible benefits that significantly enhance value.

Value addition remains central to the study's findings. Its role as a mediator, especially between sustainability orientation and FCC performance, cannot be overstated. The study of Hsu et al. (2022) also supports this finding, as they made similar observations linking CSR initiatives and value addition within supply chains. In competitive markets such as Thailand, this value addition can be the critical differentiator, enabling firms to carve out a distinct niche.

Drawing from our insight into the aforementioned relationships, it is imperative to delve into the practical implications they have within the dynamic of the cold chain industry. Industries globally are reevaluating their practices and priorities due to growing sustainability concerns. For instance, cold storage facilities, being major contributors to energy consumption and greenhouse gas emissions, are at a critical crossroads. Embracing a strong sustainability orientation, many facilities are now transitioning to more sustainable and energy-efficient solutions. A notable shift is the adoption of renewable energy and eco-friendly refrigerants, which significantly reduce carbon footprint. In addition, artificial intelligence (AI) is emerging as an instrumental tool in this sustainable revolution for cold storage facilities. The use of AI technology not only enhances continuous monitoring of activities but also sharpens operational efficiency. By aligning sustainability principles with AI's capabilities, the industry can cultivate a holistic strategy that harmoniously addresses both ecological concerns and resource optimisation. In addition to economic advantages, these sustainable transitions also facilitate the conservation of precious natural resources. Beyond the immediate environmental preservation, such conservation is paramount in safeguarding the cold chain's sustainable future. This approach, supported by our findings, highlights the pressing need for judicious resource management as the industry continues to grow. Integration practices, intrinsically tied to sustainability values, support resource conservation and further the sustainable value addition, setting the course for a more resilient and sustainable cold chain.

8 Conclusion

This study has empirically explored the relationship between sustainability orientation, FCC integration, value addition, and FCC performance. Analysis of the conceptual model has provided insight into how sustainability orientation and FCC integration affect FCC performance as both a direct effect and an indirect effect through value addition. Our results show that while sustainability orientation positively influences FCC performance, much of its effect is mediated through value addition, which highlights the pivotal mediating influence of value addition. Additionally, integration stands out as a dominant factor in its impact on performance, even surpassing the influence of sustainability. Furthermore, the study has addressed a lack of contributions to the FCC field. It has also established a foundation for future research in FCC performance, as more performance-related aspects can be incorporated into the model.

However, this research is not without its limitations. Given the quantitative nature of this study, the primary concern is its generalisability since the results may not be applicable elsewhere due to differences in regulations, infrastructures, and other regional peculiarities. Additionally, the use of snowball sampling could potentially restrict the representativeness of the data, as this method might inadvertently overlook certain segments of the target population or introduce inherent biases. Looking to the future, research endeavours should address these limitations by extending the sample to different countries to strengthen the generalisability of the findings, ensuring that the results hold across the globe. Furthermore, it may be beneficial to incorporate additional performance factors in the model for a better understanding of the dynamics of the FCC. This would provide a more comprehensive view of the interrelationships at play.

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Appendix 1: Questionnaire

Questionnaire	*Coding*
Demographic	–
1. How many years of experience do you have in the food cold chain industry?	–
2. What is the size of your company/organisation in terms of annual revenue or employee count?	–
3. In which geographic location does your food cold chain operations primarily take place?	–
4. What is your primary role or position within the food cold chain?	–
5. What is your role within your company/organisation?	–
Sustainability Orientation	
1. Firms should take an internationally leading role in the field of environmental protection	SO1
2. Firms that are environmentally oriented have advantages in recruiting and retaining qualified employees	SO2
3. The environmental performance of a firm will be considered more and more by financial institutions in the future	SO3
4. Corporate social responsibility should be part of the foundations of each company	SO4
5. Environmental problems are one of the biggest challenges for society	SO5
6. Entrepreneurs and firms need to take on a larger social responsibility	SO6

Food Cold Chain Integration	
1. To what extent do employee develop a mutual understanding of responsibilities?	IN1
2. How effectively do employee understand and address each other's pressures and concerns?	IN2
3. How accessible are employee to each other in fostering open communication channels?	IN3
4. To what extent do employee share a unified vision for the firm?	IN4
5. How well are joint objectives established that align with the shared vision?	IN5
6. How effectively do employee share relevant information within and across departments?	IN6
7. To what extent do firm promote the exchange of ideas, information, and resources?	IN7
8. How well do firm foster a cooperative approach to resolving conflicts?	IN8
9. To what extent do employee strive to maintain good working relationships?	IN9
10. How harmonious is the work environment firm cultivated?	IN10
11. To what extent do firm encourage interdepartmental collaboration and teamwork?	IN11
12. How well do firm involve relevant stakeholders in decision-making processes?	IN12
13. How effectively do firm ensure coordination and synchronisation of activities across departments?	IN13
14. To what extent does the firm plan supply chain activities collaboratively?	IN14
15. How much joint development of supply chain strategies and plans does the firm have with its key partners?	IN15
16. How frequently does the firm engage in coordination meetings and workshops to align goals and objectives with its partners?	IN16
17. To what extent has the firm established a quick ordering system with its suppliers?	IN17
18. How well are the firm's order placement and processing with suppliers automated and efficient?	IN18
19. How successfully has the firm reduced lead times and order cycle times through streamlined processes?	IN19
20. How strongly does the firm emphasise the openness of communication in collaborating with its partners?	IN20
21. To what extent does the firm transparently share information, challenges, and opportunities with its partners?	IN21
22. How frequently does the firm utilise communication channels for effective collaboration and issue resolution?	IN22
23. How much does the firm share its production planning and demand forecasted information with key partners	IN23
24. How well do the firm exchange production schedules, capacity plans, and demand forecasts with its partners?	IN24
25. To what extent does the firm utilise shared information for better coordination and responsiveness?	IN25

26. How much does the firm share inventory level information with its customers?	IN26
27. How effectively does the firm provide real-time visibility of inventory levels, stock availability, and order status for its customers?	IN27
28. To what extent does the firm proactively communicate and update its customers on inventory-related issues or delays?	IN28
Value Addition	
1. The sorting process effectively categorises and organises products based on their characteristics	VA1
2. The grading system accurately assesses the quality and attributes of the products	VA2
3. The packaging materials used adequately protect the products from physical damage and contamination	VA3
4. The packaging design is visually appealing and informative	VA4
5. The cold storage facilities maintain the appropriate temperature and humidity levels for preserving product quality	VA5
6. The quantity of products transported in the cold chain meets the demand effectively	VA6
7. The cold transport system allows flexibility in adjusting to changing transportation needs	VA7
8. Timely shipping notifications are provided to track the movement of products during transportation	VA8
9. The accuracy of maintaining the desired temperature throughout the transportation process is ensured	VA9
10. The branding efforts add value and differentiate the products in the market	VA10
11. The range of product varieties meets the diverse needs and preferences of consumers	VA11
12. The quantity of value-added products meets market demand effectively	VA12
13. Innovative processing methods are utilised to enhance product quality and appeal	VA13
14. Effective quality control measures are implemented at various stages of the cold chain	VA14
15. The monitoring of product quality parameters (temperature, humidity, etc.) is consistently performed	VA15
16. Retail displays effectively showcase the cold chain products and attract customers	VA16
17. The strategic retail locations facilitate easy access and visibility of the products	VA17
18. Regular promotional activities help create awareness and drive sales of the cold chain products	VA18
19. The retail prices of the products are competitive and reasonable	VA19
20. The availability of the products in retail outlets is consistent and reliable	VA20
Food Cold Chain Performance	
1. The production cost of the food cold chain is well-managed	FCCP1
2. The distribution cost of the food cold chain is effectively controlled	FCCP2
3. The transaction cost of the food cold chain is minimised	FCCP3

4. The profitability of the food cold chain is satisfactory	FCCP4
5. The turnover rate of products in the food cold chain is optimised	FCCP5
6. The return on investment for the food cold chain is desirable	FCCP6
7. The inventory management of the food cold chain (warehousing, capital, storage, insurance, damage and loss) is efficient	FCCP7
8. The food cold chain ensures customer satisfaction throughout the transaction process	FCCP8
9. The food cold chain demonstrates flexibility in accommodating changes in customer requirements	FCCP9
10. The food cold chain provides timely and flexible delivery options	FCCP10
11. The food cold chain effectively handles backorders	FCCP11
12. The food cold chain minimises lost sales due to stock unavailability	FCCP12
13. The food cold chain maintains a high fill rate, ensuring timely availability of products	FCCP13
14. The food cold chain consistently delivers products on time without delays	FCCP14
15. The food cold chain responds promptly to customer inquiries or requests	FCCP15
16. The food cold chain has an acceptable lead-time from order placement to delivery	FCCP16
17. The food cold chain minimises shipping errors or discrepancies	FCCP17
18. The food cold chain actively addresses and resolves customer complaints	FCCP18
19. The food cold chain maintains high product quality, including sensory properties and shelf life (appearance, taste, shelf life)	FCCP19
20. The food cold chain ensures product safety and health (salubrity, product safety)	FCCP20
21. The food cold chain provides reliable and convenient products	FCCP21
22. The production system characteristics of the food cold chain (traceability, storage and transport conditions, working conditions) are satisfactory	FCCP22
23. The food cold chain demonstrates environmental responsibility through energy use, water use, pesticide use, and recycling/reuse practices	FCCP23
24. The food cold chain effectively promotes products through promotion activities, customer service, and display in stores	FCCP24