ANALYSIS OF FACTORS INFLUENCING CHINA'S CROSS-BORDER E-COMMERCE SUPPLY CHAIN RESILIENCE BASED ON THE FUZZY DEMATEL MODEL

XINWEI PAN

An Independent Study Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Master of Science in Logistics and Digital Supply Chain - (Plan B)
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By Xinwei Pan

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Faculty of Logistics and Digital Supply Chain Naresuan University

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Title	ANALYSIS OF FACTORS INFLUENCING CHINA’S CROSS BORDER E-COMMERCE SUPPLY CHAIN RESILIENCE BASED ON THE FUZZY DEMATEL MODEL
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ABSTRACT

Cross-border e-commerce supply chain is mostly operated in a relatively fixed mode, demanding massive investments in logistics, customs clearance, and payment links, which often lead to resource underutilization, high operational costs, and inefficiencies in response to changes. It is crucial for managers to identify the factors influencing supply chain resilience, as this facilitates targeted improvement and management of resilience levels. After identifying these influencing factors, it is necessary to clarify the internal connections between different factors. Hence, this study aims to identify and analyze the factors influencing China’s cross-border e-commerce supply chain resilience and construct a relationship model of these factors based on the Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL). Firstly, an initial set of 16 influencing factors was derived from a comprehensive literature review, which was then consolidated into 10 influencing factors through structured expert validation process employing structured questionnaires with relevance and causality scoring mechanisms. Subsequently, the Fuzzy DEMATEL revealed that Agility in supply chain, Information Sharing, Government Support, and Cross-Border Logistics were identified as core factors with high prominence and

influence, actively driving the overall system performance. Finally, the research will propose plans to enhance CBEC supply chain resilience by fostering a more adaptable and robust supply chain framework suitable for dynamic global markets.

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As my tenure in graduate school approaches its conclusion, it is with a reflective heart that I finalize this thesis. I would like to express my sincere gratitude to the advisor, peers, and family members who have provided unwavering support and encouragement throughout this journey.

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I would like to express my gratitude to my undergraduate advisor, Associate Professor Ziqiang Cao, for his invaluable guidance, and steadfast support. He has been a steady source of encouragement, pushing me to engage in various competitions to deepen my professional skills and expand my knowledge base. He told me that learning is for self-improvement, and this deeply inspired me - only by truly mastering it can one lay a solid foundation for the future.

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smiles from my more seasoned self, they consistently responded with indulgent nods, transforming even the most tentative questions into springboards for profound discourse. This academic sanctuary extended beyond classroom walls - the institution's thoughtfully designed study spaces featured ergonomic furniture aligned with military precision, bathed in illumination that balanced scholarly rigor with visual comfort, as if the architects had distilled sunlight through an ivory tower prism.

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ABBREVIATIONS

CBEC	=	Cross-Border E-Commerce
CFIP	=	China Federation of Logistics and Purchasing
CFCS	=	Crisp Final Converted Scores
CVR	=	Content Validity Ratio
COVID-19	=	Coronavirus disease of 2019
DEMATEL	=	Decision-making Trial and Evaluation Laboratory
IRM	=	Influence Relation Map
SCD	=	Supply Chain Disruption
SCR	=	Supply Chain Resilience
TFNs	=	Triangular Fuzzy Numbers

CHAPTER I
INTRODUCTION

This section introduces the study's background, objectives, significance, scope, and expected outcome of the study. Briefly explain why the resilience of the cross-border e-commerce supply chain deserves further study.

Research Background

Cross-Border E-Commerce (CBEC) refers to the transaction of goods and services across international borders through the Internet and e-commerce platforms (Giuffrida et al., 2017). According to the report released by the China Federation of Logistics and Purchasing (CFIP), China's CBEC transaction market, grew from 2.1 to 15.7 trillion CNY in 2012 - 2022, as shown in Figure 1 (CFIP, 2022). This growth can be attributed to the benefits of information and communication technology, which breaks geographic constraints, allows consumers to browse and order global products through social media and online shopping apps, and emphasizes shopping convenience.

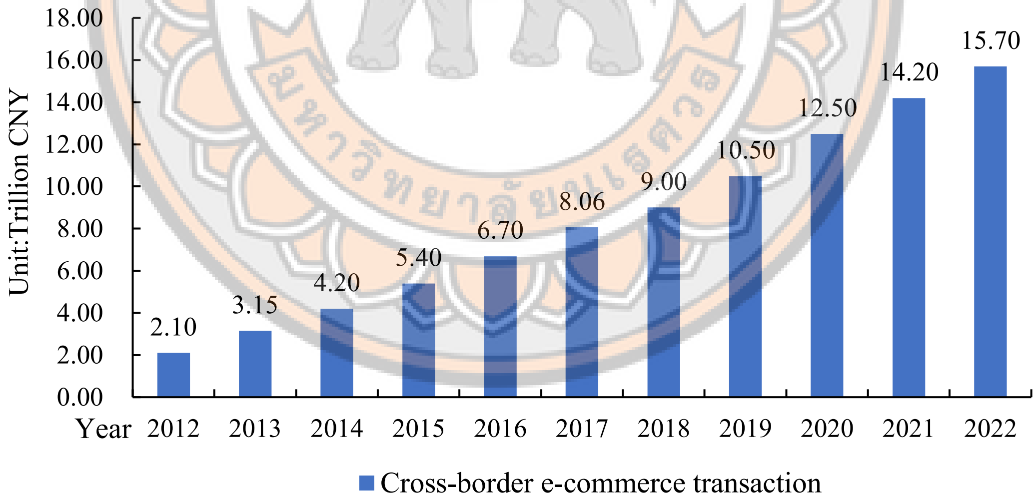


Figure 1 Transaction Scale of China's CBEC Market from 2012 to 2022

Data Source: China Federation of Logistics & Purchasing, Forward Industry Research Institute

Effective supply chain management plays an important role in CBEC (Nuruzzaman & Weber, 2021), which ensures that products can reach their destination quickly from the origin point, minimizing delays and costs. The CEBC supply chain encompasses the strategic coordination of various processes, including product procurement, warehousing, payment and settlement, customs clearance, and international logistics. Consumers place orders for the required goods on the CBEC platform. After the E-Commerce enterprise accepts the order, it packages and transports the goods to the consolidation warehouse, completes customs clearance by formalities, and then sends them to the destination country through various modes of transport (e.g., train, plane, sea). Upon arrival, after customs inspection and the payment of taxes and fees, the goods are finally sorted by warehouse staff and delivered to the customer via postal services or express delivery (Fang & Wang, 2021a), as shown in Figure 2.

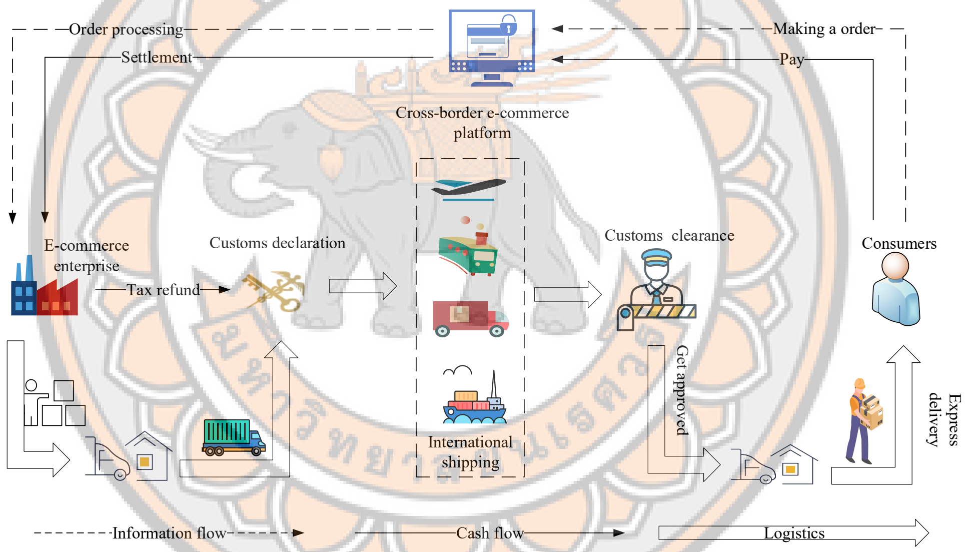


Figure 2 Cross-Border E-Commerce Supply Chain Process

The CBEC supply chain frequently encounters unpredictable operational risks and uncontrollable disruption risks. Operational risks refer to interruptions caused by uncertainties related to an organization's daily operational activities, which may result from internal processes, personnel, and systems (Christopher & Peck, 2004). Disruption risks, stemming from unforeseen events such as natural disa sters (Edwards, 2020), geo-political events (Elluru et al., 2019), and so on, pose a significant threat to the supply chain system. Such risks can lead to severe economic losses for businesses, potentially resulting in bankruptcy or closure (Kinra et al., 2020; Tang, 2006).

The outbreak of the Coronavirus disease 2019 (COVID-19) pandemic led to a global economic crisis with widespread shutdowns, and transporting challenges for many CBEC businesses, such as strict international transport regulations during the pandemic, including border closures, reduced flights, stringent quarantine measures, extended delivery times, and increased logistics costs (Kirk & Rifkin, 2020). The upheaval had a profound impact on the CBEC supply chain, as interconnected nodes in the supply chain meant that events, large or small, at any point could trigger chain reactions throughout the entire system (Bogataj & Bogataj, 2007; Kaur & Singh, 2022; Mentzer et al., 2006; Pettit et al., 2013; Tang, 2006). Hence, against the backdrop of frequent disruptions in the supply chain, resilience in the supply chain is recognized as a way to manage risks associated with interruptions (Al Naimi et al., 2022; Pettit et al., 2019; Raoufi & Fayek, 2021). Supply Chain Resilience (SCR) refers to the supply chain can recover a depleted state or evolve into an ideal state as soon as possible in the face of external shocks and internal changes (Shishodia et al., 2023).

Enhancing the resilience of a supply chain can make a trade-off by balancing the capabilities in resilience and the vulnerabilities (Carvalho et al., 2012; Razmi et al., 2017). Pettit et al. (2010) said that the enhancement of resilience in the supply chain while simultaneously reducing vulnerabilities leads to greater resilience. Indeed, the bolstering of resilience is contingent upon the establishment of effective mitigation strategies and the availability of reaction options within the system when faced with disruptions, as highlighted by Azadeh et al. (2014). It's crucial to pinpoint those capabilities that significantly boost the resilience of the supply chain (Razmi et al., 2017). However, given the difficulty in amplifying all capabilities, decision-makers should prioritize and enhance factors deemed most critical for augmenting supply chain resilience (Razmi et al., 2017). Liu et al. (2021) and Zhang et al. (2023) stated that there is relatively limited research on the resilience of supply chains in CBEC. At the same time, the factors influencing are significant, yet it is not essential to implement all of them simultaneously.

To better understand the resilience of CBEC supply chains, this study uses a literature review and Fuzzy Decision-making Trial and Evaluation Laboratory (DEMATEL). It aims to identify the factors affecting resilience, explore their relationships, and create a structured model to explain how these factors influence each other.

Research Significance

These influencing factors will serve as a practical guide for decision-makers and industry practitioners in assessing and fortifying the resilience of the CBEC supply chains.

Research Objectives

There are three objectives of this study:

(1) Identify the influencing factors that impact the resilience of the CBEC supply chain.

(2) Determine the complex interrelationships among influencing factors that impact the resilience of the CBEC supply chain.

(3) Propose plans to increase the resilience of CBEC.

Research Scope

The study will analyze the influencing factors of China's CBEC supply chain resilience. Research in this area can enhance our understanding and refine the existing influencing factors. Further, the study sought to identify a structured list of criteria associated with the influencing factors. These criteria will serve as a practical guide for decision-makers and industry practitioners in assessing and fortifying the resilience of their CBEC supply chains. A model to analyze influencing factors of the CBEC supply chain resilience using a Fuzzy DEMATEL.

This study will employ two survey questionnaires. The first survey, conducted through Tengxu meetings with experts from March to April 2024, aims to identify the key factors influencing the resilience of the CBEC supply chain. The second survey, also carried out from May to July 2024, will explore the complex interconnections among these identified factors, using expert input to uncover deeper insights.

Expected Outcome of the Study

In this study, there are three expected outcomes:

(1) A prioritized list of key factors with their degrees of influence on the CBEC supply chain resilience.

(2) A visual representation of the interconnections among influencing factors, highlighting which factors play a central role in shaping the CBEC supply chain resilience.

(3) Clear and actionable plans proposed to improve the CBEC supply chain's resilience against disruptions.

Key Words

Cross-border e-commerce, Supply chain resilience, Fuzzy DEMATEL, Affecting factors.

CHAPTER II
LITERATURE REVIEW

This chapter analyses the relevant literature to examine the current state of research on CBEC supply chain resilience. It reviews the development of CBEC, identifies the factors affecting supply chain resilience, and highlights relevant methodologies discussed in the literature. The in-depth literature review on the topic has been conducted using the given literature map in Figure 3.

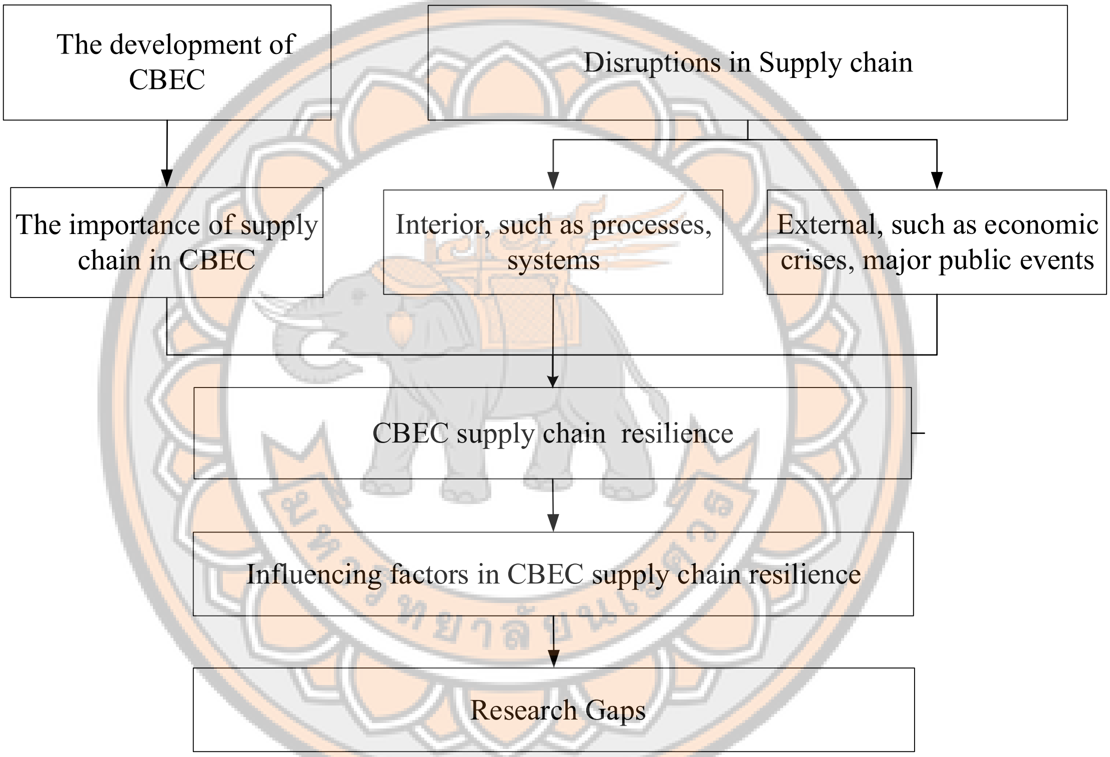


Figure 3 Literature Review Map

The Development of CBEC

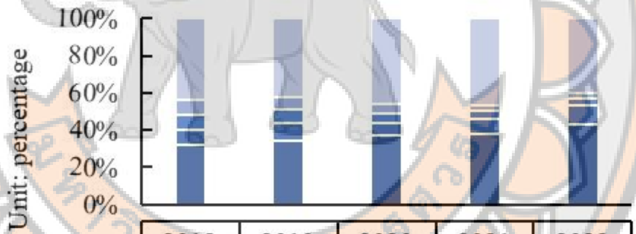
China's CBEC first emerged in 1997 (Mi et al., 2021), marking the beginning of a significant evolution in international trade facilitated by digital platforms. Early adopters of this model operated online stores on platforms such as eBay, selling popular electronic items like MP3 and MP4 players. Increasingly CBEC is noted for its capacity to lower trade barriers and stimulate the expansion of international trade (Ding, 2018; Terzi, 2011). China's status as one of the largest e-commerce markets is noteworthy, primarily due to the vastness of its consumer base.

The initiation of China's Belt and Road Initiative is shown in Figure 4. The Belt and Road Initiative has notably expanded the global reach of Chinese CBEC enterprises, significantly elevating the demand for cross-border products. By the end of 2019, there were over 23,265 CBEC companies in China, with Tmall International and NetEase Kaola emerging as successful business-to-customer platforms (Mi et al., 2021).

Figure 4 One Belt and One Road

Source: (KAPAHI, 2017)

From a channel perspective, as shown in Figure 5, Chinese e-commerce predominantly relies on mature overseas channels such as Amazon, with a gradual expansion of market share by domestic platforms. Chinese export oriented CBEC enterprises typically operate on third-party platforms such as Amazon, Alibaba, eBay, Wish, and a few have their independent sites. Overseas platforms (Amazon, eBay, and Wish) held significant market shares from 2018 to 2022; however, this share has been gradually decreasing, while domestic platforms for overseas expansion (such as AliExpress) have been expanding their market share year by year. With the continuous increase in overseas traffic costs and intensifying competition, many sellers' independent sites have witnessed a decline in market share. This trend reflects sellers' strategic adjustments to avoid excessive reliance on a single platform. In a fiercely competitive environment, over-reliance on a particular platform may pose potential risks. Therefore, most sellers opt to diversify business risks by establishing a presence on self-operated websites. The layout of self-operated websites requires merchants to independently handle traffic diversion, fulfillment, and other aspects, making it relatively more independent and autonomous. As the overseas traffic dividend gradually wanes and traffic costs rise, the requirements for retention and repurchase rates on self-operated websites become higher. Hence, brand merchants strive to offer higher-quality products and more reliable customer experiences on self-operated websites, aiming to better meet consumer needs and enhance their competitiveness in the fiercely competitive market. In summary, the decline in the market share of independent sites is closely related to sellers' strategic adjustments for risk diversification and brand building. In the context of the gradually diminishing overseas traffic dividend and intensifying competition, sellers seek independence and controllability through the layout of self-operated websites.



Years	2018	2019	2020	2021	2022
other	44%	42%	46%	47%	40%
Wish	8%	7%	5%	3%	3%
eBay	8%	7%	5%	4%	4%
AliExpress	8%	10%	7%	8%	10%
Amazon	32%	34%	37%	38%	43%

Figure 5 Evolution of Cross-Border Business to Consumer E-Commerce Channel Distribution in China

Data Source: Customs

The Chinese government is also strongly supporting the development of CBEC (He et al., 2023). China has established a comprehensive pilot zone for CBEC in the country (as shown in Figure 6), which is committed to promoting the development of the CBEC industry. A comprehensive pilot zone refers to the implementation of technical standards, business processes, regulatory models, and information construction in the realms of CBEC transactions, payments, logistics, customs clearance, tax rebates, and foreign exchange settlements are crucial for addressing the deep-seated contradictions and institutional challenges hindering the development of CBEC (Lu & Wang, 2016; Zhang & Ran, 2023). Through the avenues of institutional innovation, management innovation, service innovation, and synergistic development, there is a concerted effort to establish a comprehensive industrial and ecological chain for CBEC (Liu et al., 2023). This endeavour aims to progressively develop a management system and set of rules capable of both adapting to and leading the global evolution of CBEC.

As of January 2022, there are a total of 132 CBEC comprehensive pilot zones, covering 31 out of 34 provinces, regions, and municipalities, forming a development pattern of land-sea linkage and east-west two-way mutual assistance in the country (iresearch, 2022).

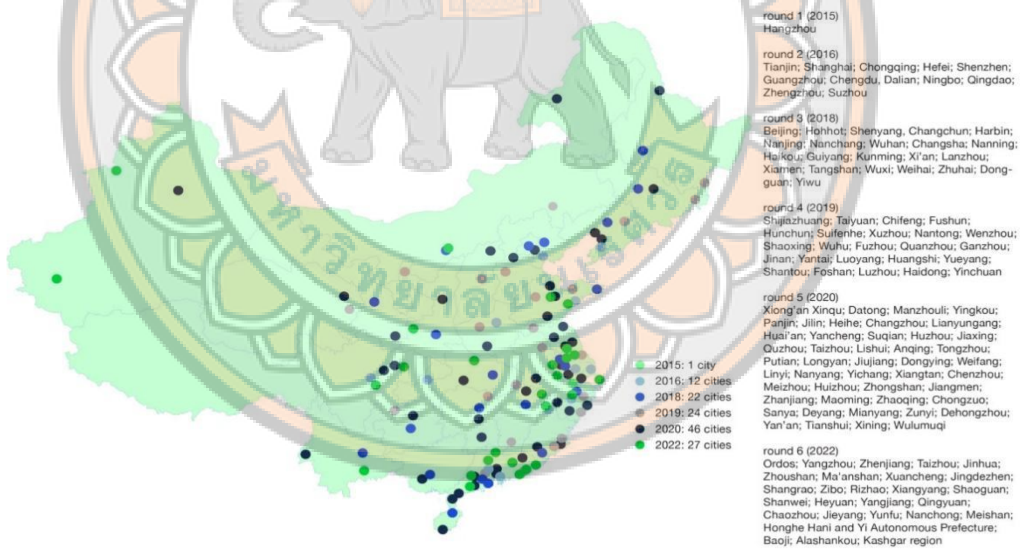


Figure 6 CBEC Comprehensive Pilot Zones

Source: (Briefing, 2024)

The Importance of Supply Chain in CBEC

The development of CBEC relies on the supply chain, whether it is the front-end manufacturer production, or the back-end payment, logistics, customs clearance, and other services, all affecting the development of e-commerce enterprises. Supply chain refers to an integrated manufacturing process in which raw materials are transformed into final products that are then delivered to customers (Beamon, 1998). The supply chain consists of procurement and production processes and circulation and consumption processes, as shown in Figure 7. The first is the procurement and production process, which includes the procurement phase from the selection of suppliers, contract negotiation to order processing, and the production process of converting raw materials into finished products. The second is the distribution and consumption process, which includes the logistics, warehouse management and distribution process of the product from the manufacturing location to the final point of sale, and the sales process of the product from the retailer to the final consumer. These two processes are linked to each other to build a complete ecosystem of the supply chain, ensuring that products flow efficiently to the market and meet consumer demand.

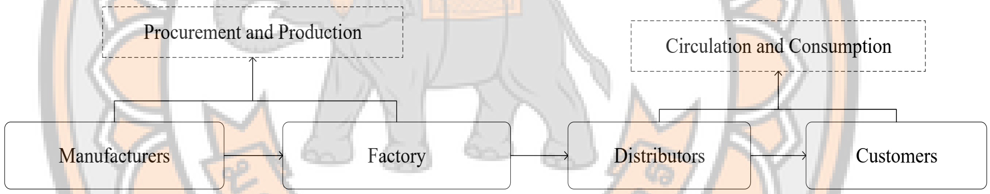


Figure 7 Supply Chain Process

Smith (1956) said that supply chain integration and synergies are key to achieving consistent and smooth product delivery. Matsui (2020) pointed out a comprehensive model for the "CBEC + supply chain", which integrates critical components such as cross-border sourcing, processing, distribution, returns, and other fundamental aspects of goods management. Particularly, relevant in a globalized economy, where businesses must navigate the complexities of international sourcing and distribution channels. Cross-border sourcing allows companies to connect with global suppliers digitally and instantaneously in response to consumer demands, thereby achieving a globalized procurement strategy. In the production segment, these enterprises possess the flexibility to manage production autonomously, select the most efficient methods, or to collaborate with manufacturing firms, optimizing global production locales. Regarding warehousing, the establishment of overseas storage facilities enables proximity to target markets, enhancing logistical operations through international aviation, maritime shipping, and multimodal transport methods. In the sales domain, CBEC enterprises directly engage with a global consumer base via various platforms, including e-commerce, social media, and proprietary online sites (eBay, amazon, AliExpress), which have augmented the supply chain's adaptability and global integration. The integration of information technology has fortified supply chain collaboration, ensuring seamless information flow, enabling real-time insights into consumer demands, procurement scheduling, and logistical monitoring. Innovations such as order-based purchasing and the utilization of QR codes for uninterrupted logistics tracking have significantly enhanced the supply chain's responsiveness and operational efficacy. As indicated by Gomez-Herrera et al. (2014), it simplifies transaction procedures and reduces trade costs. Effective policymakers within the European Union's Digital Single Market can promote CBEC.

The significance of the supply chain in CBEC cannot be overstated, as it is foundational to the efficiency, reliability, and overall success of businesses operating in this domain.

Disruption Risks in Supply Chain

Recent events have subjected the supply chains of numerous companies to unprecedented levels of disruption and testing (Cajal-Grossi et al., 2023). A disruption in the context of supply chain management can be defined as an unforeseen event that disrupts the customary progression of material flow within a supply chain network (Ivanov, 2021). After an emergency, the supply chain deviates from the expected operating state in terms of logistics, information flow, and capital flow due to external or internal factors (Bode & Macdonald, 2017), as shown in Figure 8. External factors include natural disasters, political instability, supplier problems, etc., while internal factors may involve decision-making judgment and internal mismanagement. Regardless of their source, these factors create different disruptions to the supply chain, such as demand disruptions, supply disruptions, and transportation disruptions. The level of disruption in the supply chain has a direct impact on its operational performance. Minor disruptions may only cause fluctuations in the supply chain, in which case traditional supply chain management methods can be continued. When disruptions escalate, it is possible to trigger supply chain disruptions that can lead to more severe impacts, and the introduction of SCR management is an effective strategy.

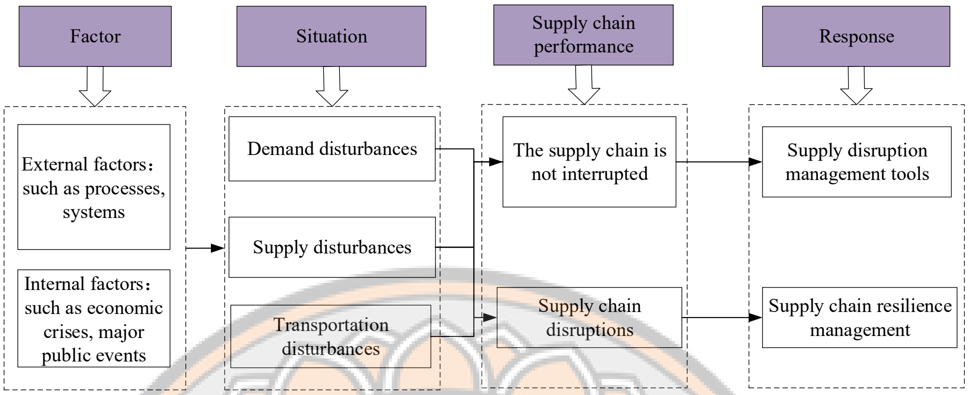


Figure 8 Supply Chain Disruption

Source: adopted (Bode & Macdonald, 2017)

The disruption is characterized by its substantial adverse impact on the operational efficiency and overall performance of the supply chain. After a risky event, the supply chain can deviate from its expected operational state, which is driven by both operational and disruption risks, as shown in Figure 9. Operational risks include demand being uncertain, information is not communicated promptly, cooperation being uncertain, etc., while disruption risks may involve natural disasters, and political instability. Regardless of their source, these risks create different impacts on operational performance. Disruptions at the level of tier-1 suppliers invariably exert an immediate and direct influence on raw material suppliers. operations. Given this immediate impact, the process of identifying and assessing the risk profiles of these tier-1 suppliers demands meticulous attention. Equally critical, however, is the acknowledgment that disruptions within the lower-tier (tier-N) suppliers, even those considered minor in scale, can precipitate consequences of a magnitude comparable to those stemming from tier-1 supplier disruptions. The cascading effect of disruptions in these lower tiers can be profound, owing to the interconnected nature of supply chains.

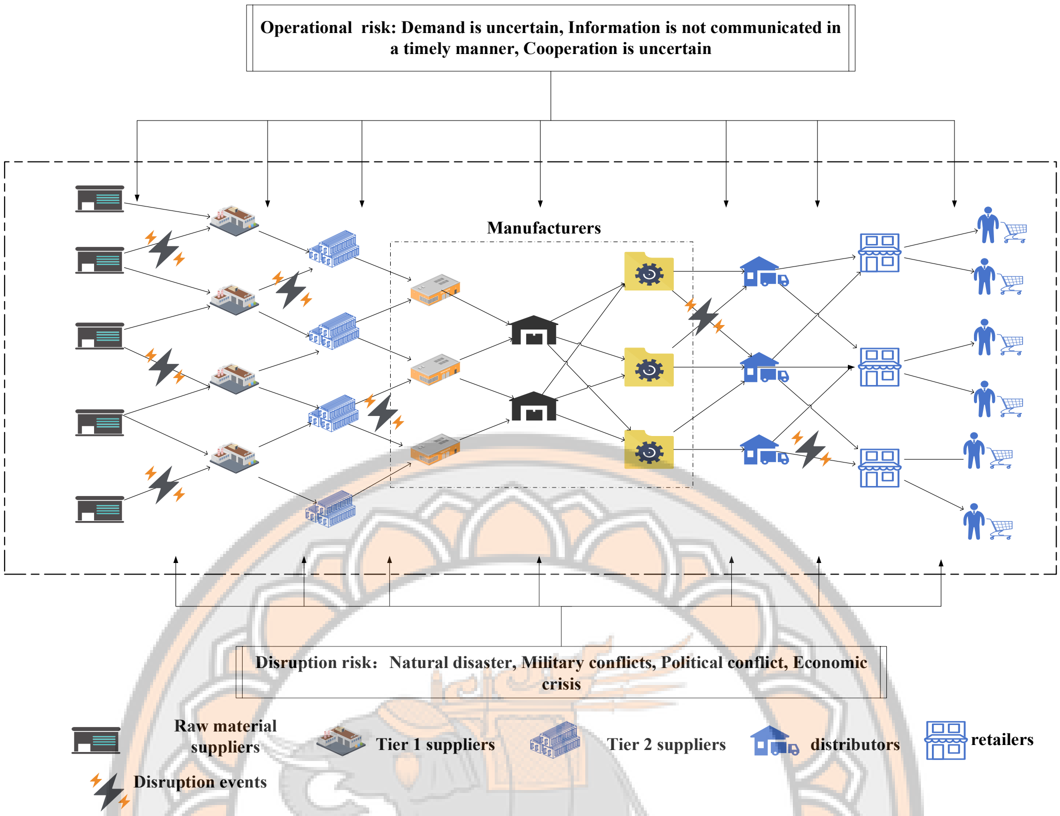


Figure 9 Supply Chain Disruption in Supply Chain

The risk of supply chain disruption can be conceptualized as the deviation from business objectives brought about by alterations in supply chain attributes or environmental changes. Such disruptions impede the normal operation of the supply chain, consequently obstructing the planned production and operational activities of the enterprise over a given period.

Disruptions may be localized, confined to a specific segment or node within the supply chain, and precipitate cascading effects throughout the network. Alcantara and Riglietti (2015) surveyed 426 sample organizations and found that more than 74% of companies had at least one supply chain disruption due to a supply chain shock, and 6% of them even experienced 6 to 20 supply chain disruptions.

It is generally said that a ripple effect appears when supply chain disruption. The concept of the ripple effect in supply chain management, as elucidated by Dolgui et al. (2018), refers to the phenomenon where a disruption extends beyond its initial localized point, creating a cascading impact that reverberates through the downstream segments of the supply chain. This effect is not merely confined to the immediate vicinity of the disruption but proliferates, affecting the performance of the entire supply chain network.

Supply Chain Resilience

The term “resilience” initially emerged within the realm of physics, where it was used to describe the property of materials to return to their original shape or position after being bent, stretched, or compressed. This concept underwent a significant transformation when it was introduced into the field of ecology by Crawford Stanley Holling (1973), whose pioneering work expanded the application of resilience beyond its physical connotations, using it to describe the ability of ecosystems to absorb disturbances and still maintain their basic function and structure. Since then, numerous authors have coalesced around a shared understanding of the concept of resilience, particularly emphasizing its significance as a system’s capacity for recovery and return to its original state (Angeler & Allen, 2016; Christopher & Peck, 2004; Cui, 2017; Kamalahmadi & Parast, 2016; Mandal, 2014; Nemuel, 2017; Pettit et al., 2010).

Azadegan et al. (2020) stated that contemporary supply chains are functioning within a milieu characterized by heightened uncertainty and intensified competition. The uncertain and intensified competitive landscape in today’s global market presents a multitude of disruptions to supply chains. Hence, resilience has attained paramount importance in the field of supply chain management. This aims to assist supply chain systems in better coping with unforeseen disruptions, risks, and challenges, including those arising from external factors such as market changes and internal factors such as operational or decision-making errors within various nodes of the chain, ensuring the system's normal operation and a swift return to stability, as shown in Figure 10.

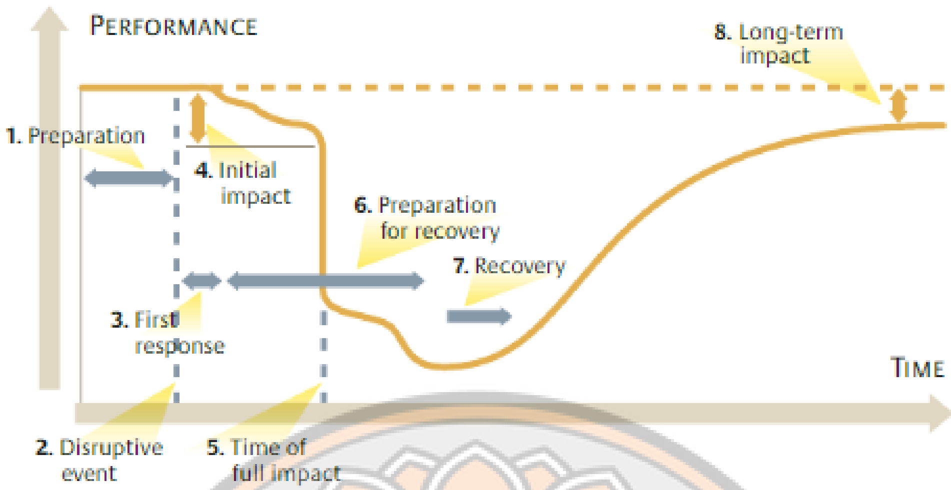


Figure 10 Act after Supply Chain Disruption

Source: based on (Sheffi & Rice Jr, 2005)

1. Preparation: Proactively anticipate and recognize potential events that could disrupt the supply chain. This step includes evaluating risks like natural disasters, geopolitical conflicts, supplier instability, and technology breakdowns.

2. Risk Assessment and Mitigation: Analyze the possible effects of identified disruptions and formulate strategies to lessen their impact. This could involve expanding the supplier base, building redundancy into essential operations, and establishing risk management frameworks.

3. First Response: As soon as a disruptive incident occurs, initiate a swift response aligned with established emergency protocols. This may require mobilizing crisis management teams, ensure employee safety, and conduct an initial assessment of the disruption's impact on the supply chain.

4. Initial Impact Evaluation: Promptly determine the scale of the disruption and its immediate effects on the supply chain, including production, logistics, and operational stability.

5. Communication: Set up reliable communication channels to keep stakeholders updated on the situation and the measures being implemented to resolve the disruption.

6. Full Impact Evaluation: Conduct a thorough review of the event's full implications, including any cascading effects on suppliers, clients, and other parties involved in the supply chain.

7. Recovery: Implementation of Recovery Plan: Execute the prepared recovery plan, focusing on restoring critical functions, re-establishing supplier relationships, and minimizing further disruptions.

8. Long-Term Impact: Analyse the disruptive event and the response to identify lessons learned. Evaluate the effectiveness of the preparedness, response, and recovery strategies. Use insights from the disruptive event to enhance the overall resilience of the supply chain. Implement changes to processes, technology, and strategies to better prepare for future disruptions.

As depicted in Figure 11, scholars categorize supply chain resilience into pre-disruption preparedness, in-disruption response capability, and post-disruption recovery capability (Chowdhury & Quaddus, 2017; Sheffi & Rice Jr, 2005). Preparedness refers to the measures taken by businesses before potential risks and disruptive events occur to proactively prepare for unforeseen circumstances (Kamalahmadi & Parast, 2016). Response capability is the swift and effective response of businesses when disruption events occur (Kamalahmadi & Parast, 2016). Recovery capability pertains to the supply chain's ability to promptly implement effective measures based on existing resources after experiencing disruption, minimizing the negative impact on the supply chain (Kamalahmadi & Parast, 2016).

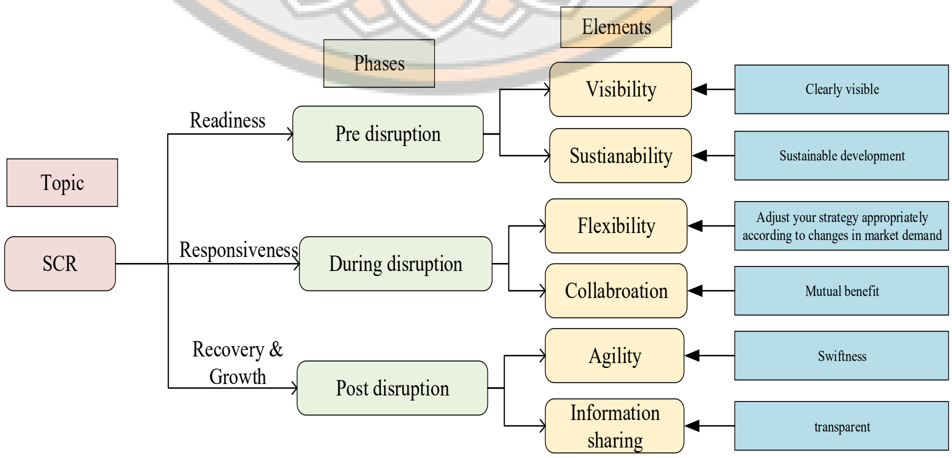


Figure 11 Theoretical Framework of SCR

Source: based on (Razmi et al., 2017)

The capability of SCR is intended to ensure the maximization of benefits with minimal costs in these aspects. Before facing potential risks, by achieving the visualization of the supply chain, businesses can gain a better understanding of overall operations and effectively monitor and assess potential risk factors. Emphasizing sustainability implies considering long-term impacts when implementing measures, ensuring the stability and sustainability of the supply chain.

When disruption events occur, collaborative capabilities enable various links in the supply chain to collectively address issues, mitigating the impact of disruptions to the maximum extent through the sharing of information and resources. Flexibility involves quickly adapting to changes, and adjusting production, supplier relationships, and logistics strategies to ensure the coherence of the supply chain.

Once the disruption is under control, businesses need to swiftly take agile measures to restore normal operations to the supply chain. Simultaneously, collaboration remains crucial at this stage, and businesses need to be closely with stakeholders, working together to restore normal production and supply.

It is essential to recognize the potential for disruption from various sources is imperative, and adequate preparation (Ke et al., 2023).

The Importance of Resilience in CBEC

The importance of resilience in CBEC is amplified by the digital nature of e-commerce platforms, where customer expectations for rapid delivery and seamless service are high. Even minor disruptions in cross-border operations can result in significant delays, customer dissatisfaction, and financial losses. Therefore, building resilience in the supply chain enables companies to meet customer expectations while mitigating the risks associated with cross-border transactions.

Resilient CBEC supply chains are essential for maintaining business operations, preserving customer satisfaction, and protecting revenue streams when faced with unexpected disruptions such as pandemics, political turmoil, or natural calamities (X. Liu et al., 2021).

To comprehensively understand and address various challenges and threats faced by supply chains. Engineering resilience focuses on the technical and operational capabilities of the supply chain, while ecological resilience emphasizes sustainable and environmentally friendly supply chain management (X. Liu et al., 2021). Economic resilience centers on the supply chain's adaptability under economic pressures, and social resilience considers the social relationships within the supply chain.

Resilience of CBEC supply chain means that, in the face of interference events, CBEC supply chain restores its structure or function to the original state or a new ideal state by improving the adaptability of supply chain, self-response ability, self-stability ability and self-sublimation ability in the face of supply chain (X. Liu et al., 2021).

Given the characteristics of CBEC supply chains involving multiple stakeholders, multiple stages, and uncertainties, resilience in the dimensions of engineering, social, economic, and ecological resilience is indeed necessary to cope with diverse challenges and changes, as illustrated in Figure 12. The resilience of the CBEC supply chain is approached through four levels and corresponding objectives. First is the focus on the ecological resilience of the supply chain as a complex adaptive system. Second is attention to the economic resilience of the supply chain amid economic uncertainty. Third is a focus on the social factors affecting the supply chain's social resilience. Fourth is the emphasis on the engineering resilience formed upstream and downstream of the supply chain. Ecological resilience aims to ensure the harmonious coexistence and coordination of the supply chain with its ecosystem, including considerations of environmental impact, resource utilization, and the adoption of renewable energy sources. Economic resilience emphasizes financial sustainability and resistance, encompassing aspects of market fluctuations and economic strength. Social resilience pertains to the dependence on social systems, including personnel, culture, ethics, and social responsibility factors within the supply chain. Engineering resilience involves the physical and technological aspects of the supply chain, encompassing the reliability of technical systems and the robustness of information systems. This is crucial as the normal operation of the supply chain relies on a series of engineering and technological systems that may face various unforeseen events and failures.

Although the objectives of these four levels of supply chain resilience differ, they are interconnected and mutually influential. Robust engineering resilience can enhance the supply chain’s ability to withstand pressure in terms of technology and structure, while good ecological resilience implies better coordination with the external environment. Strong social resilience may contribute to the establishment of more robust collaborative relationships and social networks, thereby enhancing ecological resilience.

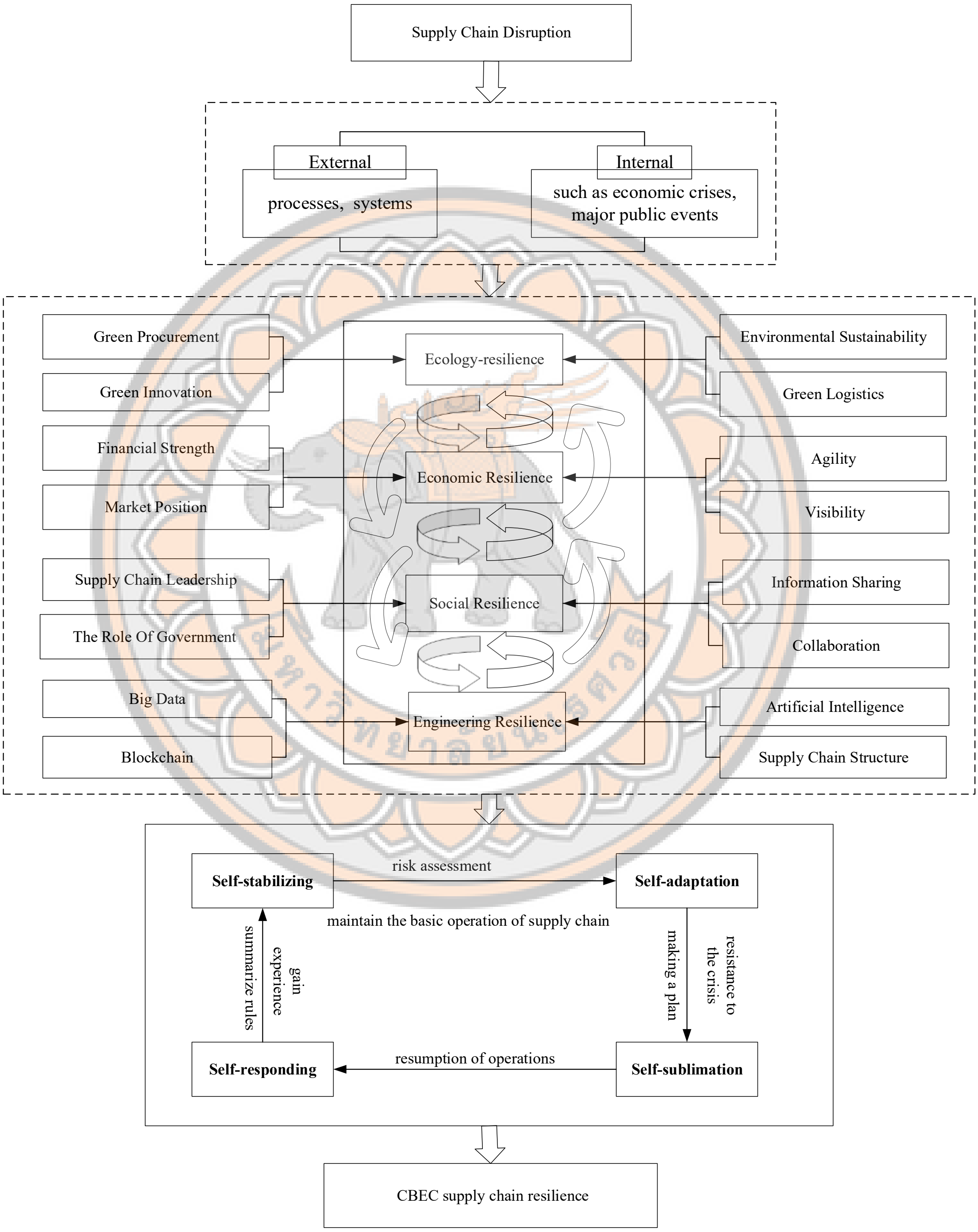


Figure 12 CBEC Supply Chain Resilience Map

Influencing factors in CBEC Supply Chain Resilience

Influencing factors play a crucial role in elucidating the reasons behind the occurrence of a particular phenomenon and the way it unfolds. Through the examination of a diverse array of potential factors, which can deepen their understanding of success. At the same time, it also faces some obstacles, such as complex regulations and customs procedures, cargo transportation delays, cargo backlog, and cultural and language barriers (Van Heel et al., 2014).

A search was performed in databases like Elsevier and Google Scholar, utilizing key phrases including "cross-border e-commerce," "supply chain resilience," and "factors of influence." While these supply chain resilience drivers were initially proposed for the general supply chain, we believe they may still be appropriate for CBEC supply chain resilience (Zhang et al., 2023).

During this phase, relevant studies were selected and analysed to identify specific resilience factors for CBEC supply chains. Additionally, references cited in these studies were reviewed to expand the analysis, which led to the inclusion of 10 further studies. To maintain consistency, only research published between 2016 and 2023 was included in the final review, resulting in a curated set of 30 articles. From these, 16 factors influencing CBEC supply chain resilience were identified, as shown in Table 1.

Table 1 A List of the Influencing Factors Identified from Related Literature

No.	Influencing Factors	Sources
1	Agility in Supply Chain	(Yadav & Samuel, 2022); (Chen & Huang, 2022); (Sarker et al., 2023)
2	Information Sharing	(Qureshi et al., 2023); (Zhang et al., 2023); (Sunmola et al., 2023)
3	Inventory Management	(Yazdanparast et al., 2021); (Priyadarshini et al., 2022); (Zhang et al., 2023)
4	Customer Demand Variability	(Giuffrida et al., 2017); (Zhang et al., 2023)
5	Visibility in Supply Chain	(Qureshi et al., 2023); (Zhang et al., 2023); (Sarker et al., 2023)
6	Cross Border Logistics	(Stoerk et al., 2019); (Giuffrida et al., 2020); (Lu et al., 2023);
7	Government Support	(Singh et al., 2019); (X. Liu et al., 2021)

8	Pay and Credit System	(Dahbi & Benmoussa, 2019); (Kofi Mensah & Simon Mwakapesa, 2021); (Lu et al., 2023);
9	Trust with Partner	(Thitimajshima et al., 2018); (Guo et al., 2018); (Al Naimi et al., 2022)
10	Geographic Distribution	(Chen & Huang, 2022); (Sarker et al., 2023); (Wang et al., 2023)
11	Risk Management Culture	(Yazdanparast et al., 2021); (X. Liu et al., 2021); (Al Naimi et al., 2022)
12	Cross Border Logistics Infrastructure	(Lu & Wang, 2016); (Sassi, 2023);
13	Artificial Intelligence	(Zouari et al., 2021); (Al Naimi et al., 2022); (Tang et al., 2023)
14	Customs Clearance	(X. Liu et al., 2021); (Zhou et al., 2022)
15	Cybersecurity Measures	(Alwan et al., 2023); (Luo & Choi, 2022)
16	Staff Training and Development	(Bevilacqua et al., 2020); (Qureshi et al., 2022); (Das et al., 2022)

Fuzzy Decision-Making Trial and Evaluation Laboratory

Fuzzy Set Theory

Given the human capacity for both intuitive and rational thinking, decision-making inherently involves a degree of vagueness, making the precise numerical evaluation of data a complex undertaking (Malviya et al., 2024). The absence of specific data further obstructs the reconstruction of the actual situation, and the inevitability of uncertainty and vagueness in the judgments made by decision-makers is a challenge that is difficult to circumvent. People frequently encounter difficulties when attempting to articulate the relationships between different factors with absolute numerical values, instead opting for the use of linguistic terms for descriptive purposes (Desbalo et al., 2023).

The theory of fuzzy sets, initially proposed by Lotfi Aliasker Zadeh in 1965, constitutes atheory and methodology for studying and handling fuzzy phenomena. It is employed to address issues in design that involve fuzzy concepts. Fuzzy mathematics quantifies fuzzy concepts through a method that transforms them into clearer information for processing and computation (Gupta et al., 2021; Tanveer et al., 2023).

The fuzzy logic, each number, falling within the range of 0 to 1, conveys a degree of partial truth, while a crisp set is aligned with the binary logic values of 0 or 1 (Malviya et al., 2024). Fuzzy logic facilitates precise mathematical judgments (Malviya et al., 2024). The conventional fuzzy linguistic scale is substituted by its equivalent, known as Triangular Fuzzy Numbers (TFNs) (Opricovic & Tzeng, 2003).

A fuzzy subset $\tilde{A}$ of a universal X is defined by a membership$f_{\tilde{A}}(X)$ function (Khompatraporn & Somboonwiwat, 2017). As one of the most popular representations of fuzzy sets, TFNs can be expressed as triplets; a set of 3 real no. i.e., *l*, *m*, and *r*, as shown in Table 2 and Figure 13.

$X^{mij} = (l_{ij}, m_{ij}, r_{ij})$ where$1 \leq m \leq M$, to be fuzzy assessment that the m^{tn} decision makers give about the degree to which factor i influence factor j. given by the decision maker n where $n = 1, 2, \ldots . N$. The membership function of TFNs is expressed in figure 8 (Malviya & Kant, 2014; Malviya et al., 2024).

$$\mu_{\widetilde{N}} = \begin{cases} (x-l)/(m-l) & l \leq x \leq m \\ (r-x)/(r-m) & m \leq x \leq r \\ 0 & x > r \text{ } or \text{ } x < l \end{cases}$$

where l, m, respectively represent the lower limit and upper limit of the fuzzy number, *r* is the most likely value.

Table 2 Transformation of Linguistic Variables and Triangular Fuzzy Numbers

Linguistic variables	Influence Score	Triangular Fuzzy Number
No influence (NO)	0	(0.00,0.00,0.25)
Very low influence (VL)	1	(0.00,0.25,0,50)
Little influence (L)	2	(0.25,0,50,0.75)
High influence (H)	3	(0.25,0,75,1.00)
Very high influence (VH)	4	(0,75,1.00,1.00)

Source: adopted (Sharma et al., 2024)

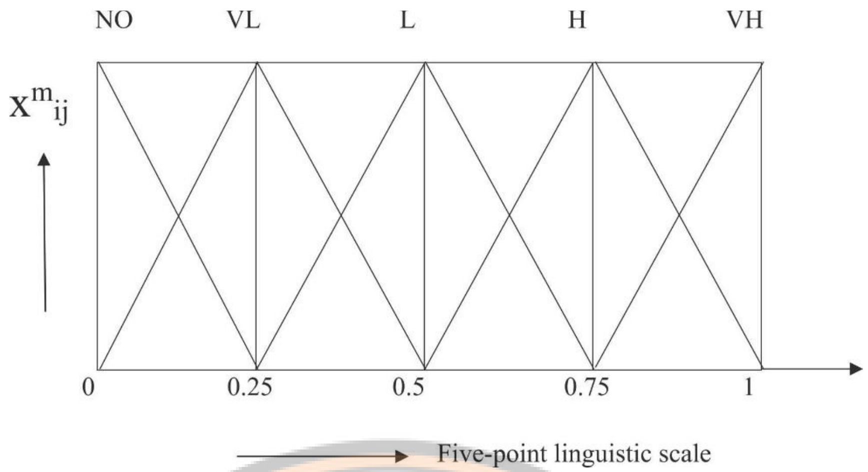


Figure 13 The Membership Function of the Triangular Fuzzy Number

Source: adopted (Malviya & Kant, 2014; Malviya et al., 2024)

Decision-Making Trial and Evaluation Laboratory

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) proposed by (Gabus & Fontela, 1972) who resolution of complex system problems, is an analytical method that uses a structural model to solve complex problem, utilising a matrix and related mathematical theories to calculate the cause and effect to each element (Zolfani & Ghadikolaei, 2013). Particularly well-suited for dealing with issues that are complicated by feedback and interdependencies among factors or elements within a system (Hung et al., 2012). DEMATEL method could improve understanding of the specific problematique, the cluster of intertwined problems and contribute to identification of workable solutions by a can identify the interdependence among the elements of a system through a causal diagram. The causal diagram uses digraphs rather than directionless graphs to portray the basic concept of contextual relationships and the strengths of influence among the elements (Kumar & Dash, 2016).

CBEC supply chain encompasses a multitude of factors, including external environmental factors, technological factors, organization factors, and others. By employing DEMATEL to construct a model, it becomes possible to quantitatively express the relationships between these influencing factors, thereby simplifying the complexity inherent in the system.

The DEMATEL method effectively harnesses the knowledge and expertise of decision makers for the evaluation and management of intricate real-world challenges, particularly in situations where the relationships between factors, as observed within CBEC supply chain, remain ambiguous. In a system, the development of entities, subject to the influence of numerous factors inherent to the system and the intricate interplay among them, is affected by these influencing factors, whether they originate from within the system or are introduced externally, exerting varying degrees of influence on the progression of entities. The DEMATEL steps as shown in Figure 14.

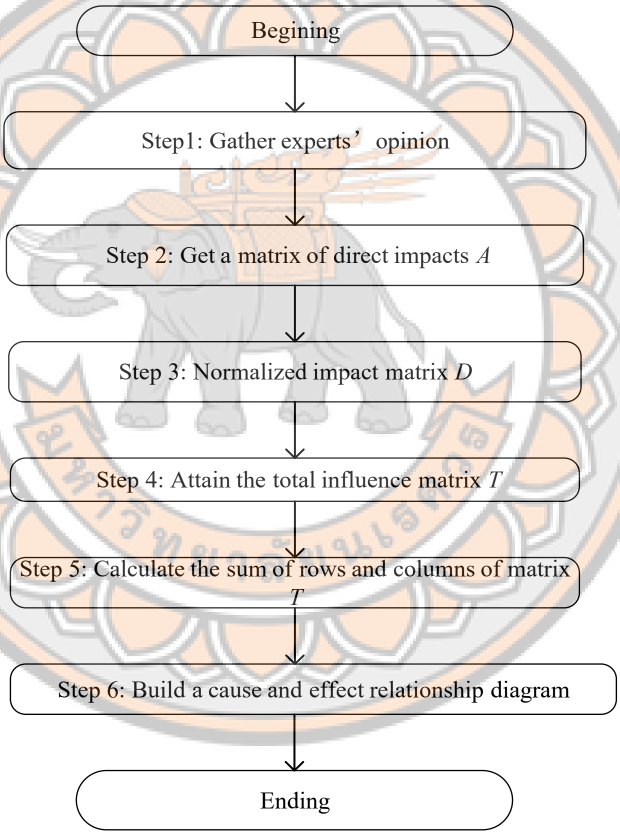


Figure 14 DEMATEL Steps

The DEMATEL method provides a structured approach to understanding and addressing complex problems through the analysis of causal relationships among factors. Here are some steps involved in the DEMATEL method:

Step 1: Form an expert group of decision makers and gather the assessments about the direct effect between each pair of factors. If we have k number of experts and n number of factors at the end of this step, k matrixes with n*n dimension are the results. x_{ij} Shows the decision makers' judgments about the impact of factor i on factor j on each matrix. Typically, factors' impacts are evaluated on a scale ranging from 0 to 4 (0 = "no influence"; 1 = "little influence"; 2 = "medium influence"; 3 = "strong influence"; and 4 = "very strong influence") (Gabus & Fontela, 1972; Si et al., 2018; Vaz-Patto et al., 2024)

Step 2: Construct the direct-relation matrix (A). Collecting data through pairwise comparisons to assess the direct influence each factor has on every other factor from experts' opinion. A = [a_{ij}] indicates the direct impact value of factor i on factor j. The initial direct relation matrix A can be obtained through by equation (1):

$$a_{ij} = \frac{1}{k}\sum_{k=1}^{k} x_{ij} \tag{1}$$

Step 3: Normalized the initial direct relation matrix (D). This step ensures that the sum of each row does not exceed and ensures the matrix's stability and comparability. Normalized the initial direct relation matrix D can be obtained through equation (2):

$$D = \frac{1}{max \prec i \prec n \sum_{j=1}^{n} a_{ij}} A \tag{2}$$

Step 4: Calculate the total-relation matrix (T). This matrix can be used the formula equation (3). I is the identity matrix, and $(I - D)^{-1}$ is the inverse of $(I - D)$. The Total-Relation Matrix (T) provides a holistic view of the relationships among factors by considering the immediate influence of one factor on another.

$$T = D(I - D)^{-1} \tag{3}$$

Step 5: Determining the sum of rows and columns from the total-relation matrix (T) provides crucial insights into the influence dynamics within the system. The sum of the rows and columns of T is written as the vectors D and R, as shown in the formula (4).

$$\begin{aligned} D &= (D_i)_{n\times 1} = \left[\sum\nolimits_{j=1}^{n} a_{ij}\right]_{n\times 1} \\ R &= (R_i)_{n\times 1} = \left[\sum\nolimits_{j=1}^{n} a_{ij}\right]_{1\times n} \end{aligned} \tag{4}$$

Where D_i is the i^{th} row sum in the matrix T and displays the sum of the direct and indirect effects dispatching from factor a_i to the other factors. Similarly, R_j

is the j^{th} column sum in the matrix T and depicts the sum of direct and indirect effects that factor a_j is receiving from the other factors (Gabus & Fontela, 1972).

Regarding the diagonal elements, where $i = j$, the horizontal axis vector (D_i+R_j) named "Prominence" illustrates the overall effects that factor i both gives out and receives within the entire system (Si et al., 2018). As a result, (D_i+R_j) can clearly indicate "the degree of importance of factor i in the whole system" (Jindal et al., 2021). If the prominence value is higher than that of other factors, it indicates that the factor is more significant in the system's overall dynamics. what's more, the vertical axis vectored (D_i-R_j) "Relation" shows the net effect that the factor contributes to the system (Si et al., 2018). If the value D_i - R_j > 0, indicates that the factor is cause factor, oppositely, if the value D_i - R_j < 0, indicates that the factor is effect factor.

Step 6: Build the cause-and-effect diagram.

According to use the prominence and relation values to plot the factors in a cause-and-effect diagram (IRM - Influence Relation Map), which visually represents the cause-effect relationships among factors, highlighting which factors are most influential and how they impact each other. As shown in Figure15, the y-axis represents the relation values (D_i - R_j), and the x-axis represents the prominence values (D_i + R_j).

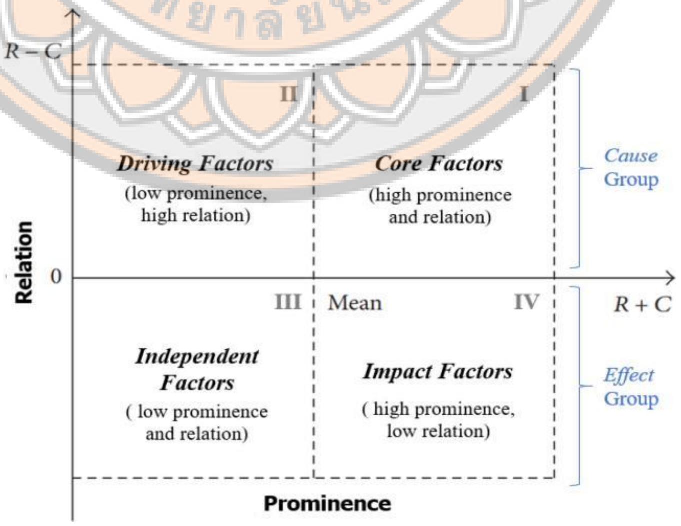


Figure 15 The Cause-Effect Relationship Diagram

Source: adapted from Si et al. (2018); Vaz-Patto et al. (2024)

In addition, the diagram is divided into four quartiles (QI–QIV), which separate the determinants or factors into (1) core factors in QI, which means the value (D_i - R_j) is positive and prominence values (D_i + R_j) high of the factor, reveals that the factor is a cause factor and actuating factor for solving the problem; (2) driving factors in QII, which means the value (D_i - R_j) is positive and prominence values (D_i + R_j) small of the factor, revealed that the factor is an independent factor and influences only a small number of other factors. (3) independent factors in QIII, which means the value (D_i - R_j) is negative and prominence values (D_i + R_j) small of the factor, revealed that the factor is an independent factor and influences only a small number of other factors; and (4) impact factors in QIV, the value (D_i - R_j) is negative and prominence values (D_i + R_j) high of the factor, revealed that the factor is a core problem that requires resolution (Tsai et al., 2017).

Fuzzy Decision-making Trial and Evaluation Laboratory

The Fuzzy Decision-making Trial and Evaluation Laboratory (Fuzzy DEMATEL) is an advanced analytical method used for complex decision-making scenarios. It integrates the principles of fuzzy logic into the traditional DEMATEL approach, enhancing its ability to handle uncertainty and imprecision in human judgments. This approach aims to eliminate the subjectivity inherent in expert scoring.

The Crisp Final Converted Scores (CFCS) approach, originally proposed by Opricovic and Tzeng (2003), stands as one of the most widely utilized defuzzification techniques within fuzzy logic systems and the Fuzzy DEMATEL framework.

The specific steps involved in the CFCS method are outlined as follows:

(1) Normalization of Fuzzy Numbers: Normalize the fuzzy numbers to ensure comparability across different scales. This is done by applying min-max normalization to each component of the TFNs:

$$\begin{aligned} xr_{ij} &= (r_{ij} - \min l_{ij}) / \Delta_{\min}^{\max} \\ xm_{ij} &= (m_{ij} - \min l_{ij}) / \Delta_{\min}^{\max} \\ xl_{ij} &= (l_{ij} - \min l_{ij}) / \Delta_{\min}^{\max} \end{aligned} \tag{5}$$

Where, i is row factor, j is column factor, $\Delta_{\min}^{\max} = \max r_{ij} - \max l_{ij}$.

(2) Left and right spread measures of normalised fuzzy numbers: The left and right spread measures of normalized fuzzy numbers are critical components in the defuzzification process—especially when using methods like CFCS—because they help preserve the shape and uncertainty characteristics of the original fuzzy numbers.

$$xrs_{ij} = xr_{ij} / (1 + xr_{ij} - xm_{ij}) \tag{6}$$

$$xls_{ij} = xm_{ij} / (1 + xm_{ij} - xl_{ij})$$

(3) Compute total normalised crisp score:

$$xij = \left[xls_{ij}(1 + xls_{ij}) + xrs_{ij} \times xrs_{ij}) \right] / (1 - xls_{ij} + xrs_{ij}) \tag{7}$$

(4) Compute crisp value:

$$aij = \min l_{ij} + xr_{ij} \times \Delta_{\min}^{\max} \tag{8}$$

The Fuzzy DEMATEL process flow, depicted in Figure 16.

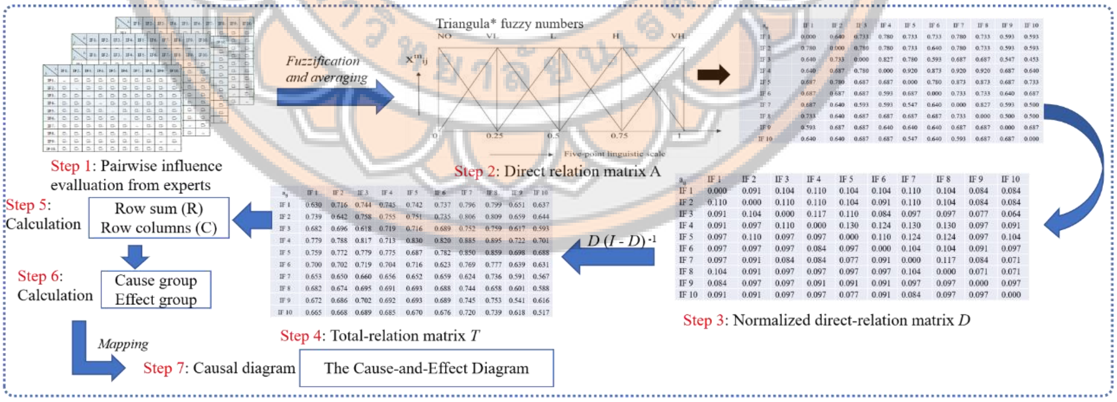


Figure 16 Fuzzy DEMATEL Steps

Step 1: Form a committee of decision makers and gather the assessments about the direct effect between each pair of factors.

Step 2: The fuzzy language scale is designed (as shown in Table 2) and combine the formula (1) and the formula (5-8), the fuzzy initial direct impact matrix A is obtained.

Step 3: The canonical direct influence matrix is obtained, using the formula (2).

Step 4: Obtain the defuzzification of the total influence matrix, combining equations (3) (Razmi et al., 2017).

Step 5: The sum of the rows and columns of T is written as the vectors D and r, by using the formula (4).

Step 6: Calculate prominence ($D_i + R_j$) and relation ($D_i - R_j$).

Step 7: Construct the cause-effect relationship diagram and structural model of the system (Razmi et al., 2017).

Applications of Fuzzy Decision-making Trial and Evaluation Laboratory

The Fuzzy Decision-making Trial and Evaluation Laboratory (Fuzzy DEMATEL) has wide-ranging applications and is recognized as a powerful tool for examining intricate systems by illustrating interdependencies and causal links among different elements. This tool's capability to depict cause-and-effect relationships in a clear, visual format makes it particularly valuable in contexts where understanding these dynamics is crucial for effective decision-making.

This approach is particularly beneficial for identifying key drivers, barriers, and enablers that impact various aspects of supply chains, from resilience and responsiveness to sustainability and performance, as shown in 3.

Table 3 Fuzzy DEMATEL Applications

Authors	**Research purposes**
Abadi et al. (2021)	Determining effective criteria for resilient supplier selection.
X. Liu et al. (2021)	Identify of influencing factors in the CBEC supply chain resilience.
Zameni et al. (2021)	Evaluate the causal relationships of shift work, job stress, job satisfaction with the occupational health level in a petrochemical industry.
Abdullah et al. (2022)	Exploring key decisive factors in manufacturing strategies in the adoption of Industry 4.0
Chai et al. (2022)	Identify of critical success factors for safety program implementation of regeneration of abandoned industrial building projects in China.
Sharma et al. (2022)	Identify and segregate the supply chain vulnerability factors for manufacturing enterprises based on causal–effect relationships that exist between them.

Hossain et al. (2023)	Identify and priority the factors of green lean supply chain management.
Pandey and Mishra (2023)	Identify the key factors leading to truck mining accidents and the relationships among these factors.
Patel et al. (2024)	Assessing barriers of automation and robotics adoption in the Indian construction industry.
Xu et al. (2024)	Identify the key factors influencing scientific data sharing

As supply chains continue to evolve amidst global challenges, the Fuzzy DEMATEL method's relevance is likely to grow, driving deeper, more structured insights into complex interdependencies and contributing to more resilient, sustainable practices across industries.

Research Gaps

According to previous literature, we have identified three research gaps that open new avenues for this study:

Gap One: Current research primarily focuses on studying individual or multiple factors. However, as mentioned by (X. Liu et al., 2021), literature is scarce on systematic studies. There is limited research on the influencing factors of CBEC supply chain resilience, indicating a need for more comprehensive and in-depth systematic studies.

Gap Two: There is limited research on the interrelationships among these factors. The existing literature has not thoroughly explored the complex interactions between key influencing factors of CBEC supply chain resilience. This presents another area worthy of investigation for a deeper understanding of the relationships between these factors.

Gap Three: The DEMATEL method, commonly used for analyzing factor interactions, typically relies on precise data. However, relationships between factors may exhibit fuzziness or uncertainty.

Based on the gaps, proposing a framework that aims to address the following aspects, which through the literature review, the influencing factors were selected. Then use Fuzzy DEMATEL to explore the relationship between these factors.

CHAPTER III
METHODOLOGY

Based on the research objectives, the research steps of this paper will be divided into six parts, and the specific process is as follows.

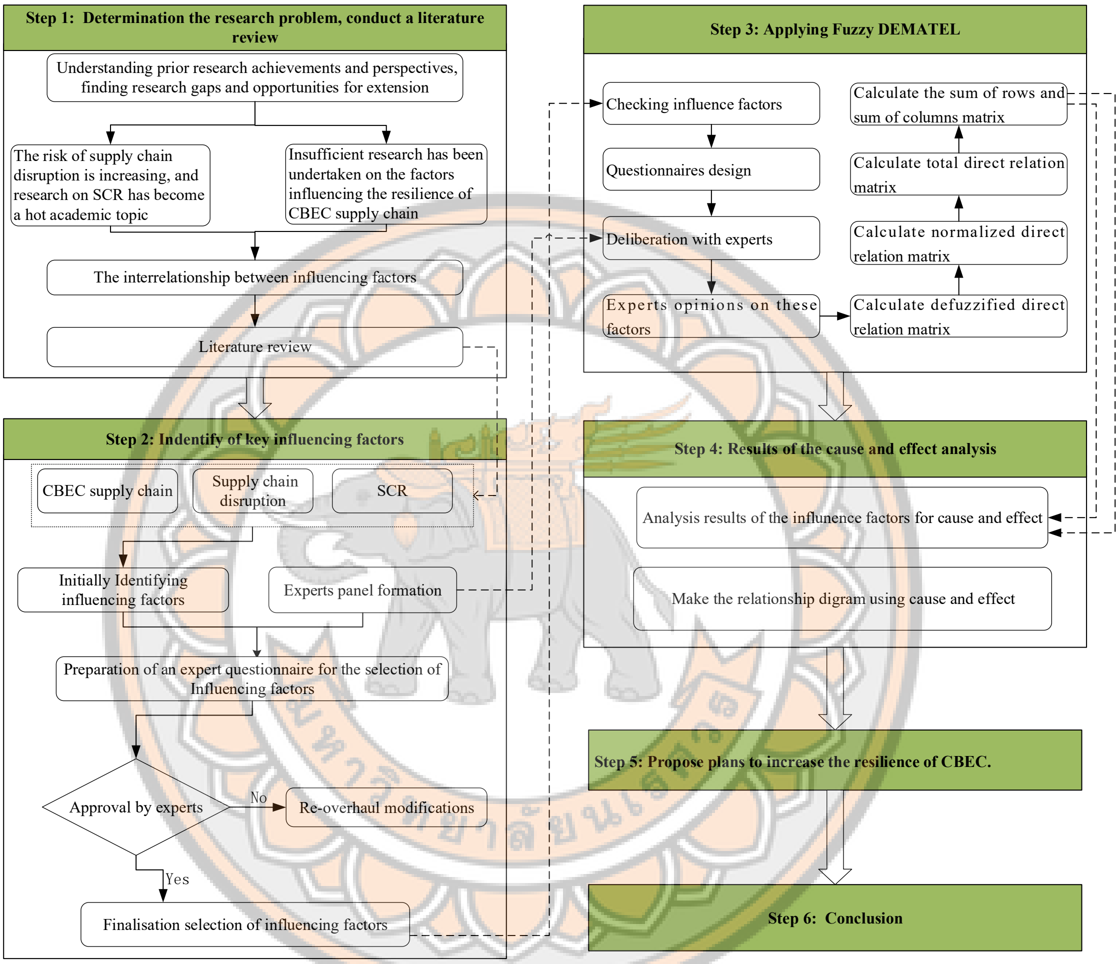


Figure 17 The Flow of Methodology

Step 1: Determination of the research problem, research objective and then conduct a literature review.

By reviewing the existing research gaps, a solid foundation has been laid for formulating precise research objectives and clarifying the specific scope of the study. In the current context, two primary motivations drive our choice of supply chain resilience as the research theme. First, although China's CBEC sector has grown amid globalization, it faces increasing risks from trade tensions, natural disasters, and supply disruptions—highlighting the need for resilience. Second, current research on influencing factors is limited. Accordingly, academic and industry sources are reviewed to gather relevant literature on CBEC and supply chain resilience.

Step 2: Identify the influencing factors.

To meet the objectives of this paper, an in-depth literature review was conducted, and experts from the CBEC academic field were consulted. First, the literature search was conducted using key terms such as "cross-border e-commerce," "supply chain resilience," and "influencing factors" across databases like Google Scholar and Elsevier. Alongside the literature review, brainstorming sessions were arranged with ten experts, who gave their opinions to refining the factors identified through the literature review. Second, to ensure the validity of the identified factors, a questionnaire was created and validated. Experts were requested to assess each factor's relevance to CBEC supply chain resilience by classifying them as "Essential," "Useful but not essential," or "Not necessary", (see APPENDIX A). Their feedback was collected to determine the importance of each factor in the study.

Step 3: Apply Fuzzy DEMATEL Model.

Following the validation of the influencing factors, the study employs the fuzzy DEMATEL method. In this stage, A questionnaire was designed to capture expert assessments of causal relationships among the factors.and was distributed to experts to clarify the cause-and-effect relationships between the identified influencing factors. This process will generate experts' questionnaires, leading to the acquisition of a set of data composed of linguistic variables. Based on the survey results, MATLAB software will be employed to code and calculate the fuzzy direct impact matrix, normalized direct impact matrix, and comprehensive impact matrix. Subsequently, the total sums of each row and column element will be computed based on the comprehensive impact matrix.

Step 4: Results of the cause-and-effect analysis.

This analyses the mutual relationships between each influencing factor. Factor analysis is primarily conducted from two perspectives: causal factors and resultant factors. Causal factors are those that actively influence other factors, while resultant factors are those influenced by other factors (Haleem et al., 2019; X. Liu et al., 2021).

Step 5: Propose plans to increase the resilience of CBEC resilience.

To formulate effective supply chain resilience enhancement plans, companies and policymakers must comprehensively analyze both the interdependencies among critical influencing factors and the distinct attributes of individual factors that may constrain resilience-building initiatives.

Step 6: Conclusion.

The study concludes with a comprehensive discussion and summary of the findings derived from the findings. The emphasis is placed on highlighting the contributions of the research, elucidating novel insights, and underlining the practical and theoretical significance of the study in the realm of CBEC supply chain resilience in China. The conclusion not only consolidates the research outcomes but also serves as a platform for envisioning the broader implications and potential avenues for future research, thereby contributing to the advancement of both theory and practice in this critical domain.

CHAPTER IV
RESULT AND DISCUSSION

This chapter presents the outcomes derived from data analysis. As outlined in Chapter III, the research process encompasses six sequential steps, with findings presented accordingly. The chapter concludes with a discussion that interprets these findings considering the study's goals.

Preliminary Identification of Influencing Factors

In the literature review, the study identified 16 primary influencing factors relevant to CBEC supply chain resilience. Here is a concise presentation of the identified influencing factors for CBEC supply chain resilience, with each factor's definition, as shown in Table 4.

Table 4 The Definition of Influencing Factors

No.	Factors	Definition
1	Agility in Supply Chain	The capacity of the supply chain to quickly adapt to unexpected changes or disruptions.
2	Information Sharing	The exchange of data and insights among supply chain partners to enhance transparency and decision-making.
3	Inventory Management	Control of inventory levels, ordering, and usage to meet customer demand efficiently.
4	Customer Demand Variability	Fluctuations in customer purchasing behavior, affecting supply chain planning and inventory needs.
5	Visibility in Supply Chain	The ability to monitor goods and information across the supply chain in real-time for better responsiveness and risk reduction.
6	Cross Border Logistics	Management of the movement and coordination of goods across international borders, ensuring efficient and compliant operations.
7	Government Support	Assistance provided by governmental entities, such as subsidies, policy support, or infrastructure development.
8	Pay and Credit System	Financial mechanisms that support transactions between supply chain partners, including credit terms and payment systems.

9	Trust with Partner	The level of confidence and reliability established between supply chain partners, promoting cooperation and risk reduction.
10	Geographic Distribution	The spatial placement of supply chain facilities and partners, influencing efficiency, costs, and responsiveness.
11	Risk Management Culture	It systematically internalized values, behavioral norms, and institutional frameworks within an organization, enacted through a tri-level mechanism of leadership commitment, employee engagement, and cross-functional collaboration.
12	Cross Border Logistics Infrastructure	Physical and technological facilities (e.g., warehouses, transportation networks, IT systems) support cross-border logistics.
13	Artificial Intelligence	Use of machine learning and data analytics to automate processes, optimize decision-making, and predict patterns in the supply chain.
14	Customs Clearance	The official procedures for moving goods through customs to comply with regulatory requirements for import/export.
15	Cybersecurity Measures	Security practices to protect digital information and systems within the supply chain from cyber threats.
16	Staff Training and Development	Programs aimed at improving employee skills and knowledge to enhance efficiency and adaptability in supply chain operations.

Note: the definition of factors from (Ali & Gölgeci, 2019; Giuffrida et al., 2020; A. Liu et al., 2021; Zhou et al., 2022)

Finalization of Influencing Factors

Based on preliminary identification, a structured questionnaire was developed and subjected to a pilot test to confirm the validity of the influencing factors. A brainstorming session was organized. These sessions involved five academic professionals, who helped refine and prioritize the factors identified in the review process. Details of the participants are provided in Table 5.

Table 5 The Details of the Participants Who Participated in Identifying factors

Experts	Affiliation	Years of work experience	Educational level
1	University	25 years or more	Doctor
2	University	10-15years	Doctor
3	University	10-15years	Doctor
4	Company	10-15years	Bachelor
5	Company	3-5-years	Bachelor

The core links of the CBEC supply chain are already covered by five experts. Adding more practitioners or scholars in the same field will easily lead to repeated views. Among this stage, the two practitioners are crucial here because they have long been engaged in the specific operation of CBEC supply chains. They can accurately identify the practical problems that are easily ignored in theoretical research. The scholar has in-depth research on cross-border supply chain risk and resilience and can sort out the influencing factors that have been verified by existing studies from many literatures, ensuring the theoretical basis of factor identification.

Based on their professional expertise and practical experience, experts were tasked with evaluating consistency and relevance influencing factors in the context of CBEC supply chain resilience. Each factor was assessed using a binary rating system: “-1” signifying “not necessary”, which means indicating the factor has little to no relevance to supply chain resilience, “0” denoting "useful but non-essential", which means moderate utility without being critical, and “1” representing "essential", which means the factor's significant relevance and contribution to supply chain resilience. The validation of the factors was conducted through expert evaluation using a structured questionnaire, as shown in Table 6.

Table 6 The Factors were Validated by Experts Through the Questionnaire

Influencing Factors	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Cross Border Logistics	1	1	1	1	1
Information Sharing	1	1	1	1	1
Inventory Management	1	1	1	1	1
Customer Demand Variability	1	0	1	1	1
Visibility in Supply Chain	1	1	1	1	1
Agility in supply chain	1	1	1	1	1
Government Support	1	1	1	1	1
Pay and Credit System	1	1	1	1	1
Trust with Partners	1	1	1	1	1
Information Sharing	1	1	1	1	1
Inventory Management	1	1	1	1	1
Cross Border Logistics Infrastructure	1	1	0	1	1
Artificial Intelligence	1	1	0	1	1
Customs Clearance	1	1	1	0	1
Cybersecurity Measures	0	1	1	1	1
Risk Management Capability	0	1	1	1	1

Based on the evaluation data of CBEC supply chain resilience factors presented in Table 6, which can clearly identify the specific number of experts who recognize each factor as "necessary". The total number of experts participating in the evaluation is five, and the specific distribution is as follows:

Among these factors, 10 factors have been recognized as "necessary" by five experts. They are Cross Border Logistics, Information Sharing, Inventory Management, Visibility in Supply Chain, Agility in Supply Chain, Government Support, Pay and Credit System, Trust with Partners, Geographic Distribution, and Risk Management Culture. This indicates that during the evaluation by the five experts, the necessity of the aforementioned factors has been fully and unanimously recognized, and they are generally regarded as indispensable core elements in the CBEC supply chain.

In addition, 6 factors have been recognized as " not necessary" by four experts. These include Customer Demand Variability, Cross Border Logistics Infrastructure, Artificial Intelligence, Customs Clearance, Cybersecurity Measures, and Staff Training and Development. This means that although these 6 factors have not reached a consensus among all experts, more than half (80%) of the experts still recognize their necessity. Only a small number of experts hold different opinions on their necessity, which reflects that there is a certain degree of cognitive difference among the expert group regarding the importance of these factors.

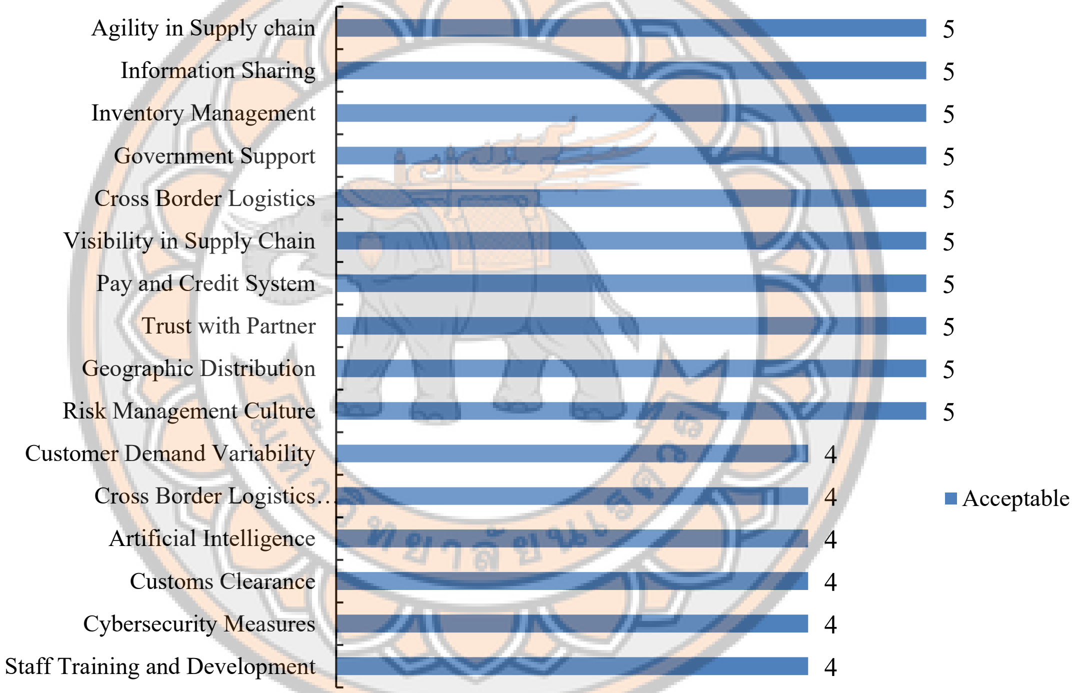


Figure 18 The Number of Experts Considering Factors as "Necessary"

With five experts assessing each factor, the minimum threshold for the Content Validity Ratio (CVR) required to retain a factor, based on Lawshe's method, was set at 0.99 (Ayre & Scally, 2014), as shown in Table 7. If the CVR is above the benchmark, retain the factor; if it falls below the benchmark, discard it (Gilbert & Prion, 2016). The detailed validation outcomes systematically presented in Table 8.

Table 7 Minimum Values of CVR

Numbers of panelists	Minimum acceptable CVR value
5	0.99
6	0.99
7	0.99
8	0.75
9	0.78
10	0.62
11	0.59
12	0.56
13	0.54
14	0.51
15	0.49
20	0.42
25	0.37
30	0.33
35	0.31
40	0.29

Source: (Ayre & Scally, 2014)

Table 8 The Result of Influencing Factors Based on CVR

Influencing Factors	Code	CVR	Valid? (≥0.99)
Agility in Supply chain	IF 1	1.0	Yes
Information Sharing	IF 2	1.0	Yes
Inventory Management	IF 3	1.0	Yes
Government Support	IF 4	1.0	Yes
Cross Border Logistics	IF 5	1.0	Yes
Visibility in Supply Chain	IF 6	1.0	Yes
Pay and Credit System	IF 7	1.0	Yes
Trust with partner	IF 8	1.0	Yes

Influencing Factors	Code	CVR	Valid? (≥0.99)
Geographic Distribution	IF 9	1.0	Yes
Risk Management Culture	IF 10	1.0	Yes
Customer Demand Variability		0.6	No
Cross Border Logistics Infrastructure		0.6	No
Artificial Intelligence		0.6	No
Customs Clearance		0.6	No
Cybersecurity Measures		0.6	No
Staff Training and Development		0.6	No

Note: $CVR = \frac{n_e - (N/2)}{N/2}$

n_e: The number of experts who consider the factor "necessary".

N: The total number of experts participating in the review.

For example, a group of five experts reached a consensus that "Supply Chain Agility" is a "necessary factor" for enhancing the resilience of CBEC supply chains. The CVR calculation result for this factor (denoted as IF1) is presented below; the calculation processes and results for other influencing factors follow the same method.

$$CVR(IF\ 1) = \frac{5 - \left(\frac{5}{2}\right)}{\frac{5}{2}} = 1.0$$

These factors include cross-border logistics, information sharing, inventory management, supply chain visibility, supply chain agility, government support, pay and credit system, trust with partners, geographic distribution, and risk management Culture. The CVR of these 10 factors is 1.0, indicating that all experts agree these factors play a crucial role in the resilience of CBEC supply chain resilience.

Supply Chain Agility (IF 1) is identified by five experts as a core determinant for cross-border e-commerce supply chain resilience, enabling real-time adaptation to dynamic market demands—from rerouting logistics to avoid geopolitical risks to optimizing inventory strategies via AI-powered demand forecasting.

Information Sharing (IF 2) ensured real-time synchronization of order, logistics, and payment data through blockchain technology, eliminating information silos and facilitating upstream-downstream collaboration.

Inventory Management (IF 3) signified ten experts' agreements on its indispensability for CBEC supply chain resilience. This factor addresses the dual challenge of minimizing holding costs and mitigating stockout risks in cross-border contexts, where lead times can extend to some weeks.

Government Support (IF 4) encompassed tariff preferences and trade facilitation policies directly enhancing supply chain flexibility.

Cross-border Logistics (IF 5) demonstrated effectiveness in multimodal transport networks—during the pandemic, some enterprises replaced ocean shipping with China-Europe Railway Express, improving delivery stability.

Supply Chain Visibility (IF 6) encompassed the ability to monitor and track goods, information, and finances across cross-border touchpoints, from manufacturing to last-mile delivery. Experts emphasized that visibility in CBEC is uniquely challenging due to multi-jurisdictional complexities, language barriers, and diverse regulatory requirements—challenges that can only be addressed through integrated technological solutions and standardized data frameworks.

Payment and Credit System (IF 7) address the complex web of cross-border financial transactions, foreign exchange risks, and creditworthiness assessments that underpin operational continuity. Experts emphasize that in CBEC—where transactions span multiple currencies, payment preferences, and regulatory frameworks, an optimized payment system is critical for mitigating cash flow volatility and maintaining supplier trust.

Partner Trust (IF 8) encompassed the relational capital built through transparent communication, contractual reliability, and shared risk mitigation strategies among cross-border stakeholders, including suppliers, logistics providers, and customs brokers. Experts emphasize that in CBEC, where cultural, legal, and operational distances amplify transaction costs, trust serves as a "relational buffer" that reduces opportunistic behavior and facilitates rapid crisis collaboration.

Geographic Distribution (IF 9) addressed the spatial optimization of production hubs, warehouses, and logistics nodes to balance cost efficiency with risk diversification.

Risk Management Culture (IF 10) enhances resilience through regular drills—one enterprise streamlined emergency response to activate backup plans within 4 hours by simulating port blockades.

Excluded factors such as customer demand variability, cross border logistics infrastructure, artificial intelligence, cybersecurity measures, and staff training and development were identified as less critical by the expert panel, reflected in lower CVR scores. These factors, while potentially valuable, were not prioritized for this study.

Interrelationships of Influencing Factors

To determine the initial degree of influence among the influencing factors within the CBEC supply chain resilience framework, the Fuzzy DEMATEL Model is employed. A structured questionnaire was distributed to gather insights from experts. The following table details the five experts participating in this stage. This questionnaire (see APPENDIX B), sent via email, included a 10×10 pairwise comparison matrix that allowed participants to evaluate the influence of each factor relative to the others.

Table 9 The Details of the Participants Who Participated in determining factors

Experts	Affiliation	Years of work experience	Educational level
1	University	10-15years	Master
2	University	10-15years	Master
3	Company	10-15years	Master
4	Company	3-5-years	Master
5	Company	3-5-years	Bachelor

The two scholars specializing in fuzzy mathematics methods have in-depth research on the Fuzzy DEMATEL Model. They have applied this model to analyze supply chain-related issues before. The operators have rich experience in multifactor decision analysis. For example, when comparing the model results of this study with international benchmark enterprises, they can focus on whether the core factors identified in this study.

Step 1: Convert Linguistic Terms into Corresponding TFNs

In this initial phase, the qualitative linguistic terms provided by experts are converted into TFNs to allow for a quantitative analysis. Based on expert assessments, these linguistic terms are transformed into TFN datasets, which are outlined in Table 2. Using the TFN-converted values, construct an initial direct-relation matrix (typically denoted as *A*) for each expert. This matrix represents the direct influence each factor has on others. During this phase, the preliminary direct-relation matrix, displayed in Table 10, was generated.

Table 10 The Fuzzy Direct-Relation Matrix (*A*)

a_{ij}	IF 1	IF 2	IF 3	IF 4	IF 5	IF 6	IF 7	IF 8	IF 9	IF 10
IF 1	0.000	0.640	0.733	0.780	0.733	0.733	0.780	0.733	0.593	0.593
IF 2	0.780	0.000	0.780	0.780	0.733	0.640	0.780	0.733	0.593	0.593
IF 3	0.640	0.733	0.000	0.827	0.780	0.593	0.687	0.687	0.547	0.453
IF 4	0.640	0.687	0.780	0.000	0.920	0.873	0.920	0.920	0.687	0.640
IF 5	0.687	0.780	0.687	0.687	0.000	0.780	0.873	0.873	0.687	0.733
IF 6	0.687	0.687	0.687	0.593	0.687	0.000	0.733	0.733	0.640	0.687
IF 7	0.687	0.640	0.593	0.593	0.547	0.640	0.000	0.827	0.593	0.500
IF 8	0.733	0.640	0.687	0.687	0.687	0.687	0.733	0.000	0.500	0.500
IF 9	0.593	0.687	0.687	0.640	0.640	0.640	0.687	0.687	0.000	0.687
IF 10	0.640	0.640	0.687	0.687	0.547	0.640	0.593	0.687	0.687	0.000

Step 2: The initial direct-relation matrix was standardized by applying formula (1) and the formula (5-8), resulting in a normalized matrix, as shown in Table 11.

Table 11 The Normalized Fuzzy Direct Relation Matrix (*D*)

a_{ij}	IF 1	IF 2	IF 3	IF 4	IF 5	IF 6	IF 7	IF 8	IF 9	IF 10
IF 1	0.000	0.091	0.104	0.110	0.104	0.104	0.110	0.104	0.084	0.084
IF 2	0.110	0.000	0.110	0.110	0.104	0.091	0.110	0.104	0.084	0.084
IF 3	0.091	0.104	0.000	0.117	0.110	0.084	0.097	0.097	0.077	0.064
IF 4	0.091	0.097	0.110	0.000	0.130	0.124	0.130	0.130	0.097	0.091
IF 5	0.097	0.110	0.097	0.097	0.000	0.110	0.124	0.124	0.097	0.104
IF 6	0.097	0.097	0.097	0.084	0.097	0.000	0.104	0.104	0.091	0.097
IF 7	0.097	0.091	0.084	0.084	0.077	0.091	0.000	0.117	0.084	0.071
IF 8	0.104	0.091	0.097	0.097	0.097	0.097	0.104	0.000	0.071	0.071
IF 9	0.084	0.097	0.097	0.091	0.091	0.091	0.097	0.097	0.000	0.097
IF 10	0.091	0.091	0.097	0.097	0.077	0.091	0.084	0.097	0.097	0.000

Step 4: Use Calculate the total relation matrix; the total relation matrix *T* is achieved from the formula (3), the result is presented in Table 12.

Table 12 The Total Relation Matrix (*T*)

a_{ij}	IF 1	IF 2	IF 3	IF 4	IF 5	IF 6	IF 7	IF 8	IF 9	IF 10
IF 1	0.630	0.716	0.744	0.745	0.742	0.737	0.796	0.799	0.651	0.637
IF 2	0.739	0.642	0.758	0.755	0.751	0.735	0.806	0.809	0.659	0.644
IF 3	0.682	0.696	0.618	0.719	0.716	0.689	0.752	0.759	0.617	0.593
IF 4	0.779	0.788	0.817	0.713	0.830	0.820	0.885	0.895	0.722	0.701
IF 5	0.759	0.772	0.779	0.775	0.687	0.782	0.850	0.859	0.698	0.688
IF 6	0.700	0.702	0.719	0.704	0.716	0.623	0.769	0.777	0.639	0.631
IF 7	0.653	0.650	0.660	0.656	0.652	0.659	0.624	0.736	0.591	0.567
IF 8	0.682	0.674	0.695	0.691	0.693	0.688	0.744	0.658	0.601	0.588
IF 9	0.672	0.686	0.702	0.692	0.693	0.689	0.745	0.753	0.541	0.616
IF 10	0.665	0.668	0.689	0.685	0.670	0.676	0.720	0.739	0.618	0.517

After that, the total relations matrix (*T*) was computed from the normalized initial direct-relation matrix. The next step involved calculating the row sums (D) and column sums (C) for all elements within the total relations matrix. Following this, the prominence (D+R) and relation (D-R) values were derived, as shown in Table 13.

Table 13 The Cause-and-Effect Groups of Influencing Factors

Factors	Code	D	R	D+R	D-R	CAUSE OR EFFECT
Agility in Supply Chain	IF 1	7.197	6.961	14.159	0.236	cause
Information Sharing	IF 2	7.297	6.993	14.290	0.304	cause
Inventory Management	IF 3	6.841	7.179	14.021	-0.338	effect
Government Support	IF 4	7.950	7.135	15.085	0.814	cause
Cross Border Logistics	IF 5	7.649	7.151	14.799	0.498	cause
visibility in Supply Chain	IF 6	6.979	7.098	14.076	-0.119	effect
Pay and Credit System	IF 7	6.447	7.690	14.137	-1.243	effect
Trust with partners	IF 8	6.715	7.785	14.499	-1.070	effect
Geographic Distribution	IF 9	6.789	6.337	13.127	0.452	cause
Risk Management Culture	IF 10	6.649	6.183	12.832	0.466	cause

Step 5: Construct cause-effect diagram. A cause-effect diagram can be generated by plotting the dataset using the values of ($D_i + R_j$, $D_i - R_j$), as shown in Figure 19.

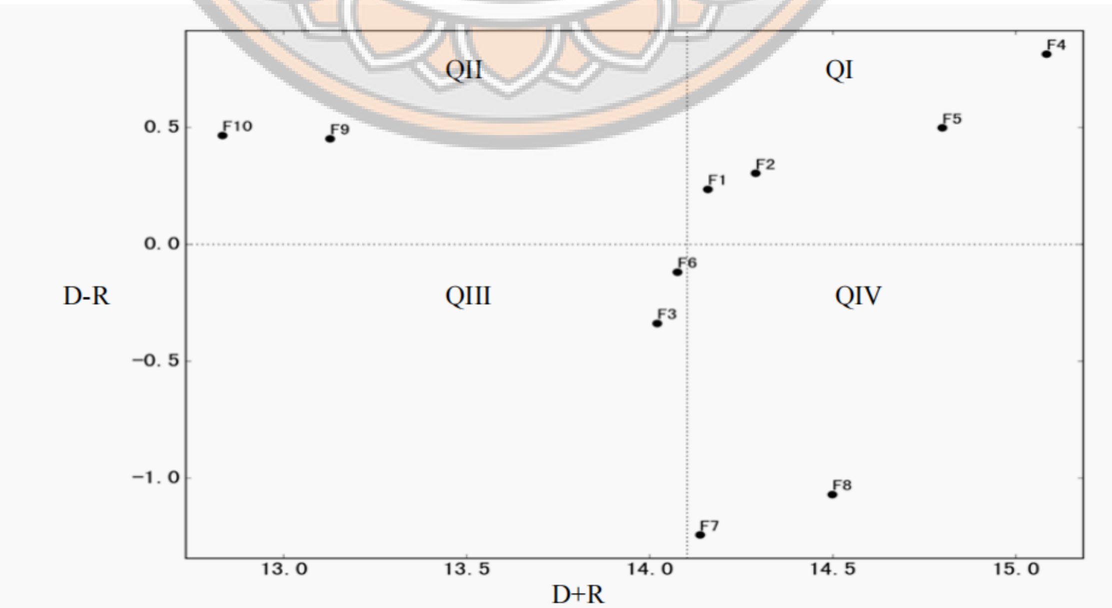


Figure 19 The Cause-and-Effect Diagram

Discussion

Findings

Before interpreting the data, it is critical to understand what each value measures— Fuzzy DEMATEL quantify cause-effect relationships and influence importance between factors by calculating two core dimensions:

- *D* (Influence Given): The total degree of influence factor *i* exerts on all other factors. A high *D* value means this factor is a strong "driver."
- *R* (Influence Received): The total degree of influence factor *j* receives from all other factors. A high *R* value means this factor is highly influenced by others.

From these, the two critical values for interpretation:

- Prominence ($D_i + R_j$): "How important and active is this factor within the system?"
- Relation ($D_i - R_j$): "Is this factor a cause or an effect?"

The Fuzzy DEMATEL-based decision framework as shown in Figure 20.

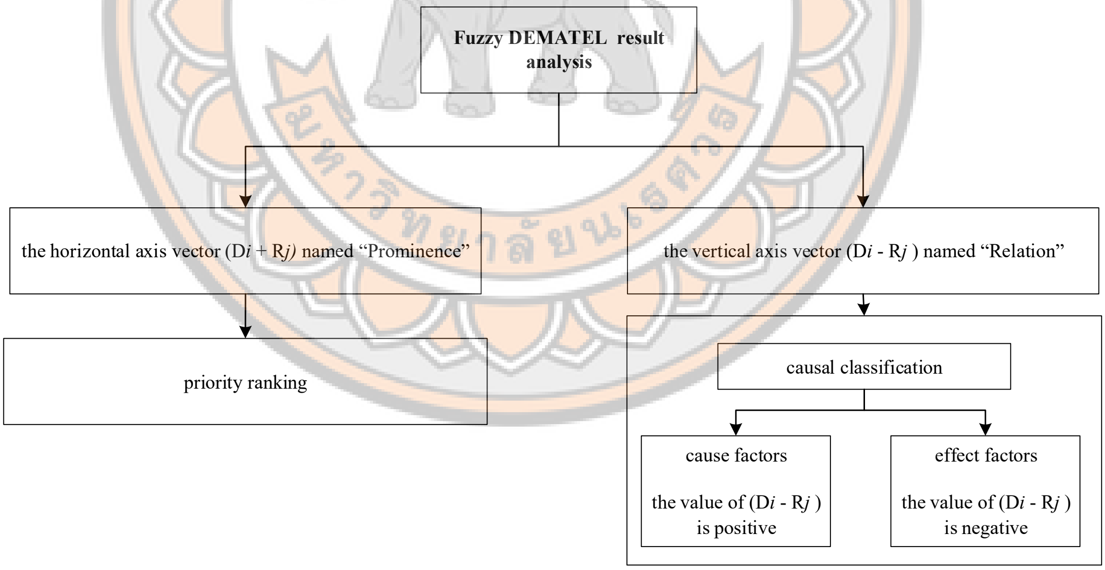


Figure 20 Fuzzy DEMATEL-Based Decision Framework

Thus, the findings of this study are structured into two components: (1) a comprehensive ranking of CBEC supply chain resilience influencing factors, (2) causal classification of these factors into cause-and-effect groups.

(1) a comprehensive ranking of CBEC supply chain resilience influencing factors

The identified influencing factors in CBEC supply chains resilience are prioritized according to (D_i + R_j) value, with detailed rankings systematically presented in Table 14. The prioritized sequence of resilience determinants in CBEC supply chains, ranked by descending (D_i + R_j) scores, unfolds as: IF4 > IF5 > IF8 > IF2 > IF1 > IF7 > IF6 > IF3 > IF9 > IF10, as shown in Figure 21.

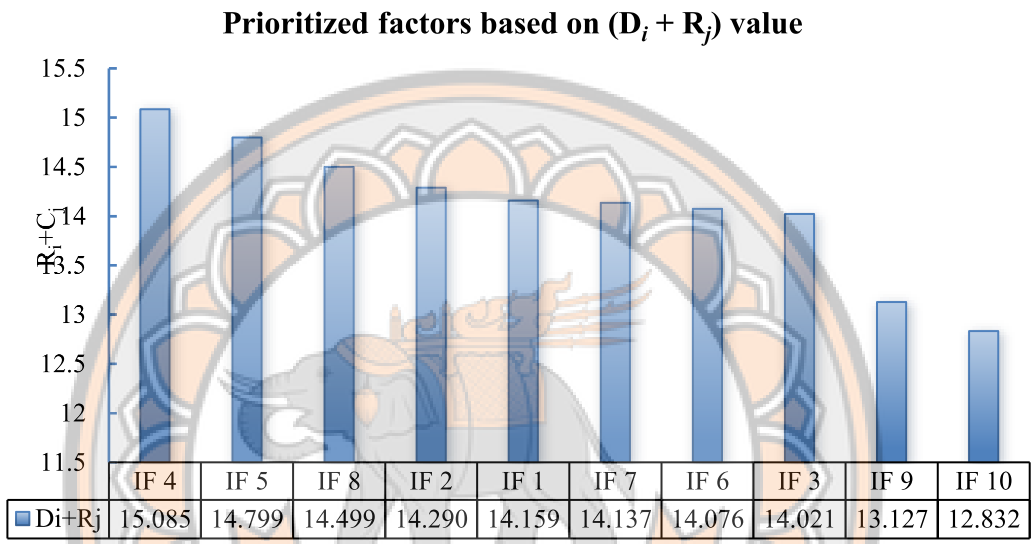


Figure 21 Prioritized Factors Based on (D_i + R_j) Value

Table 14 Factors' Prominence and Interpretation Based on (D_i + R_j) Values

Factor	**Code**	**Rank**	**D_i + R_j Value**	**Interpretation**
Government Support	IF 4	1	15.085	Any changes or policies related to government support will have the widest ripple effects throughout the entire supply chain network.
Cross Border Logistics	IF 5	2	14.799	Efficiency and policies around cross-border logistics are extremely central to the system's overall performance and stability.

Factor	Code	Rank	$D_i + R_j$ Value	Interpretation
Trust with Partners	IF 8	3	14.499	This means trust is highly dependent on other factors (e.g., information sharing, pay systems) but still matters greatly to the system.
Information Sharing	IF 2	4	14.290	The flow of information is a critical activity that connects many parts of the system.
Agility in Supply Chain	IF 1	5	14.159	The system's ability to be agile is a central and important characteristic.
Pay and Credit System	IF 7	6	14.137	It relies on others (e.g., trust, government support) but is still vital for smooth transactions.
Visibility in Supply	IF 6	7	14.076	Visibility is important but less impactful than top-ranked factors.
Inventory Management	IF 3	8	14.021	Inventory performance depends on upstream factors (e.g., logistics, visibility) but has less influence on the system overall.
Geographic Distribution	IF 9	9	13.127	Its location-related influence is less impactful than other operational actors.
Risk Management Culture	IF 10	10	12.832	It has minimal influence on others and is minimally affected by them.

(2) Causal classification of these factors into cause-and-effect groups

The influencing factors in CBEC supply chains resilience are classified into cause-and-effect groups based on (D_i - R_j) value. The corresponding relationship between D-R values and factor roles in DEMATEL analysis as shown in Table 15.

Table 15 Corresponding Relationship Between D-R Values and Factor Roles in DEMATEL Analysis

D-R Value	Classification	Core Meaning
Positive (D_i - $R_j > 0$)	Cause Factor	This factor gives more influence than it receives (D > R). It is a "driver" that actively affects other factors but is less affected by them
Negative (D_i - $R_j < 0$)	Effect Factor	The factor receives more influence than it gives (R > D). It is a "recipient" that is passively shaped by other factors but has little impact on others.

Cause factors analysis

Given that these causal factors exert a net impact on the entire system, their performance plays a critical role in shaping the overall objective. Therefore, it is generally recognized that factors in the cause group deserve close attention.

According to Table 13 and Figure 19, the findings reveal that six factors—Government Support (IF 4), Cross Border Logistics (IF 5), Information Sharing (IF 2), Agility in Supply Chain (IF 1), Geographic Distribution (IF 9), Risk Management Culture (IF 10) with positive value (D_i - $R_j > 0$) are found to be in the cause group. The ranking of six cause factors by D-R value as shown in Figure 22.

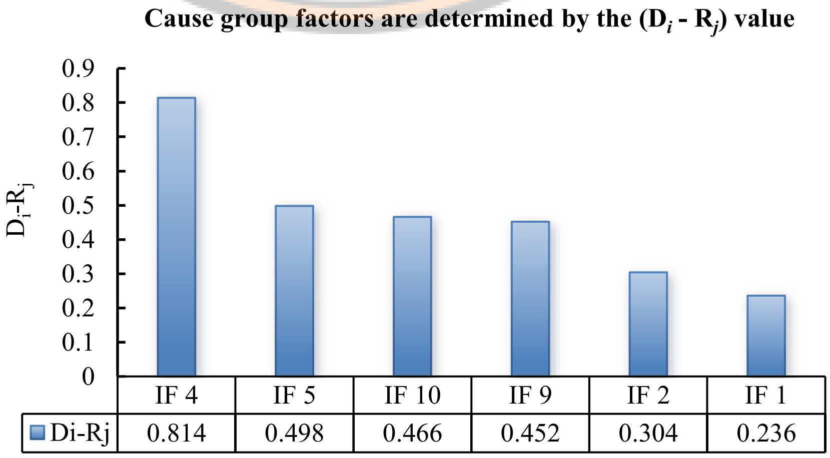


Figure 22 Cause Group Factors Are Determined By the (D_i - R_j) Value

In the cause group, Government Support (IF 4) emerges as the most influential factor within the cause group, boasting the highest (D_i - R_j) value of 0.814. However, the highest D_i score (7.95) further confirms its critical role as a primary factor, exerting the strongest systemic impact on other factors. The literature emphasizes that governmental action - particularly financial assistance and macroeconomic interventions - as a pivotal element in enhancing supply chain resilience during periods of systemic disruption (Das et al., 2022).

Cross-Border Logistics (IF 5) has the second highest (D_i - R_j) value of 0.498. Its optimization directly reduces customs delays, transportation costs, and documentation bottlenecks, thereby enhancing supply chain responsiveness. Studies highlight that digital tools like AI-driven customs clearance and blockchain-based documentation streamline cross-border operations, where perishable goods demand rapid transit (Cecil, 2024).

Risk Management Culture (IF 10) has the third highest (D_i - R_j) value of 0.466. which it as a driver that influences resilience through its impact on other factors, though it holds moderate prominence.

Geographic Distribution (IF 9) has the fourth highest (D_i - R_j) value of 0.452. For example, sourcing from multiple regions buffers against climate-related disruptions in CBEC, as seen in post-pandemic supply chain redesigns (Arıöz et al., 2024). This factor strengthens effect-group outcomes like Trust with Partners (IF 8), as consistent supply reliability builds stakeholder confidence.

Information Sharing (IF 2) has the fifith highest (D_i - R_j) value of 0.304. For example, cloud-based platforms that synchronize demand forecasts and production schedules have been proven to reduce bullwhip effects and enhance agility (Guo et al., 2024). This factor's ripple effects are evident in Inventory Management (IF 3), where real-time data reduces overstocking, and Trust with Partners (IF 8), where transparency fosters long-term collaboration.

Agility in the Supply Chain (IF 1) has the sixth highest (D_i - R_j) value of 0.236. This agility directly supports effect-group factors like Inventory Management (IF3) by balancing supply-demand mismatches and Pay and Credit Systems (IF 7) by ensuring timely fulfillment of contractual obligations.

Effect factors analysis

Factors in the effect group are more susceptible to external influence, which renders them unsuitable for consideration as critical success factors. Nevertheless, examining effect factors remains necessary to identify the specific characteristics of each.

According to Table 13 and Figure 19, Trust with partners (IF 8), Pay and Credit System (IF 7), visibility in supply chain (IF 6), Inventory Management (IF 3) with negative value (D_i - R_j < 0) are found to be in the effect group. Effect group factors are determined by the (D_i - R_j) value as shown in Figure 18.

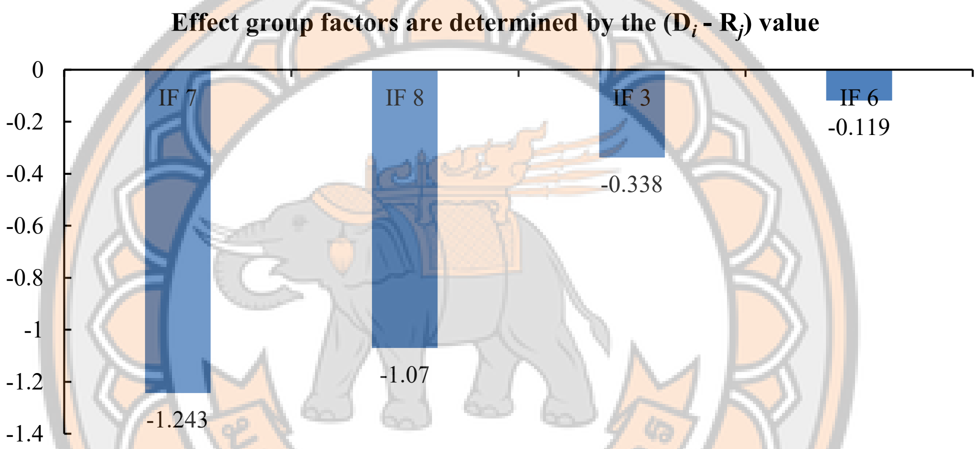


Figure 23 Effect Group Factors Are Determined By the (D_i - R_j) Value

In the effect group, Visibility in Supply Chain (IF 6) with a (D_i + R_j) value of 14.076 and (D_i - R_j) value of -0.119 and thus positioning it as a stabilizing conduit in CBEC supply chain resilience. Inventory Management (IF3) has (D_i + R_j) value of 14.021 and (D_i - R_j) value of -0.338, indicating that IF 3 plays peripheral role within the system, as it neither significantly nor is strongly influenced by other factors. This research outcome is in line with previous studies (Das et al., 2022). Trust with Partners (IF 8) has a (D_i - R_j) value of -1.07, but the third highest (D_i + R_j) value of 14. 499. The values indicate that while this factor is more heavily influenced by other factors, it also has a significant impact on others (Das et al., 2023). Pay and Credit System (IF7) were impacted by other factors (D_i - R_j= -1.243). This research outcome is in line with previous studies (Barros et al. 2020; Dora et al. 2021).

The checks for the influencing factors both in the cause group and the effect group are shown in Tables 16 and 17, respectively.

Table 16 The Checks for the Influencing Factors of Cause Group

No.	The checks for the influencing factors	Description
1	The highest degree of influence power D	Government Support (IF 4) has the highest impact power D score of 7.950; this indicates that it is one of the most important causes with a significant impact on others.
2	Highest (D_i - R_j) score in the group	Government Support (IF 4) have the highest (D_i - R_j) value of 0.814; this indicates that IF 4 is the least impacted factor by other factors.
3	Lowest (D_i - R_j) score in the group	Agility in Supply Chain (IF 1) has the lowest (D_i - R_j) value of 0.236; this indicates that although IF 1 is a causal factor, it is highly impacted by other enablers
4	Highest (D_i + R_j) score in the group	Government Support (IF 4) have the highest (D_i - R_j) value of 15.085; this indicates that management should pay attention to this factor because it reflects its most prominent overall importance in the system.

Table 17 The Checks for the Influencing Factors of Effect Group

No.	The checks for the influencing factors	Description
1	The highest degree of influence power R	Trust with Partners (IF 8) has the highest impact power R score of 7.785; this indicates that it is the most critical driver of effects within the system, exerting the strongest overall influence on other factors.
2	Highest (D_i - R_j) score in the group	Visibility in Supply Chain (IF 6) has the lowest (D_i - R_j) value of 0.236; this indicates that it is highly impacted by other factors.
3	Lowest (D_i - R_j) score in the group	Pay and Credit System (IF 7) have the highest (D_i - R_j) value of 0.814; this indicates that it is the least impacted factor by other factors.

4	Highest ($D_i + R_j$) score in the group	Trust with partners (IF 8) have the highest ($D_i + R_j$) value of 14.499; this indicates that it is highly significant compared to other factors.

In addition, based on the IRM four quartiles (see Figure 19), Agility in Supply Chain (IF 1), Information Sharing (IF 2), government support (IF 4), Cross-Border Logistics (IF 5) are core factors. The four factors have the highest ($D_i + R_j$) value and positive ($D_i - R_j$) value, which marks it as essential to the system due to its influential role and integration with other elements. Driving factors, including geographic distribution (IF 9) and risk management culture (IF 10), show strong relationships with other elements but are less prominent within the system. Inventory management (IF 3) and visibility in supply chain (IF 6) are independent factors, and, given their negative ($D_i - R_j$) values, they constitute the effect group. Impact factors, which include trust with partners (IF 8) and the pay and credit system (IF 7), exhibit high prominence but low interconnectivity, indicating their influential yet relatively isolated roles.

In summary, the Fuzzy DEMATEL analysis framework effectively categorizes and ranks the CBEC supply chain resilience factors based on their prominence and causal nature, and the calculated results from the previous analysis fit well within this framework, providing a comprehensive understanding of the factors' roles in the supply chain system, as shown in Figure 24.

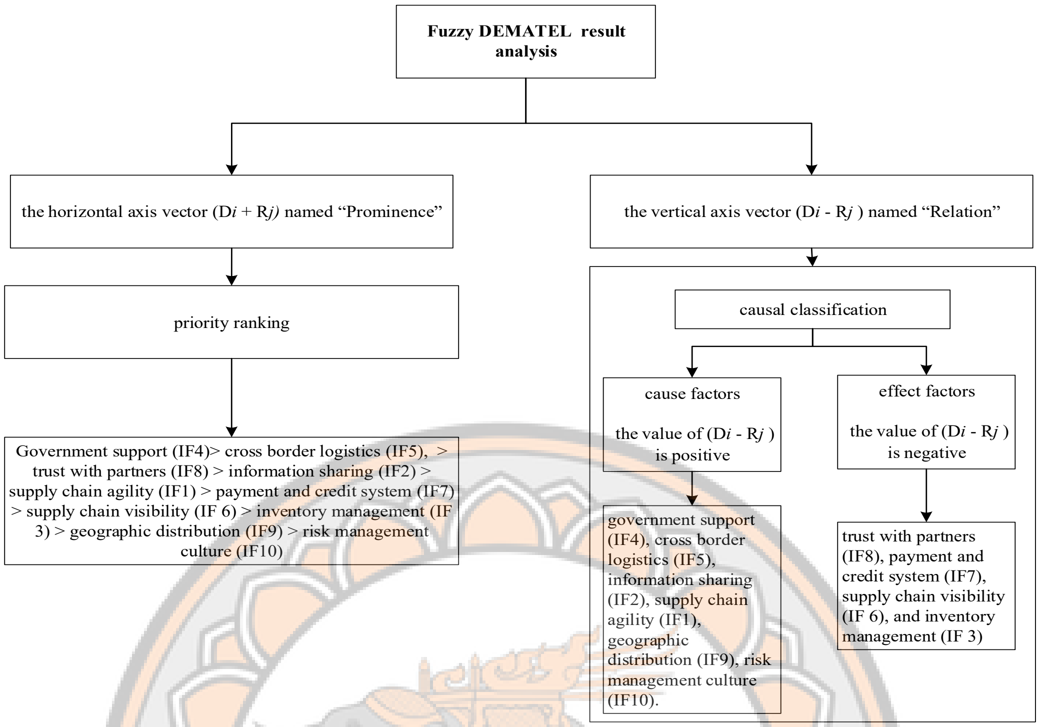


Figure 24 Fuzzy DEMATEL Results Analysis

The resilience of China's CBEC supply chain is increasingly critical due to the rapid expansion of e-commerce and the globalized nature of trade. While the industry shows significant growth potential, several challenges still impact its performance, particularly in terms of adaptability, visibility, and risk management within the supply chain. Addressing these challenges is essential to ensuring a stable and resilient CBEC ecosystem.

Formulating development plans anchored in core factors essentially involves strategically focusing and precisely allocating limited resources to critical pressure points of systemic vulnerabilities, thereby establishing a closed-loop resilience enhancement mechanism with explicit causal linkages, will be systematically examined in Chapter Five.

Comparison with Existing Studies

The findings of this study are highly consistent with the existing research on cross-border e-commerce supply chain resilience. Prior studies, such as those by X. Liu et al. (2021), Zhang et al. (2023), Chen and Yang (2021) have highlighted the significant impact of international logistics efficiency and cross-border policy changes on the resilience of China's cross-border e-commerce supply chains. The identification of Agility in Supply Chain (IF 1), Information Sharing (IF 2), government support (IF 4), Cross-Border Logistics (IF 5), as core influencing factors in this study.

In addition, many previous studies have employed qualitative analysis, statistical surveys, or conventional multi-criteria decision-making (MCDM) tools such as Analytic Hierarchy Process (AHP) or Bayesian network to evaluate supply chain resilience (e.g., Das et al. (2022), Hosseini et al. (2020), Fang and Wang (2021b)) While these methods offer structured evaluations, they often lack the ability to handle complex interrelationships between influencing factors under uncertainty. This study leverages the Fuzzy DEMATEL model, which integrates expert judgment with fuzzy logic to quantify both the strength and direction of causal relationships between factors. This provides a more nuanced, system-based analysis of cross-border supply chain resilience, capturing the interdependence of factors under ambiguity. The summary of this study has conducted a comparative analysis with existing studies, as shown in Table 18.

Table 18 The Summary of Comparisons

Dimension	Existing Studies	This Study
Research Method	Qualitative analysis, AHP	Fuzzy DEMATEL
Core Conclusion	General factor listing	Identification of key factors
Practical Value	Limited guidance for targeted improvement	Provides actionable plans for enterprises

CHAPTER V
PLANS FOR ENCHAINING THE CBEC SUPPLY CHAIN RESILIENCE

This chapter formulates targeted action plans to enhance CBEC supply chain resilience, directly derived from the above findings in Chapter IV. Based on the above findings, the cause-effect relationship diagram, four core factors that are essential for improving CBEC supply chain resilience are identified. These factors include Agility in Supply Chain (IF 1), Information Sharing (IF 2), Government Support (IF 4), and Cross-Border Logistics (IF 5). These factors are essential for resilience due to their central role in enabling real-time monitoring, information flow, and adaptability, which are critical for effectively managing disruptions in cross-border trade.

Identifying the Four Core Factors

As validated by the DEMATEL-derived cause-effect relationship diagram and factor importance rankings, four pivotal factors are identified as the "core pillars" for improving CBEC supply chain resilience: Agility in Supply Chain (IF 1), Information Sharing (IF 2), Government Support (IF 4), and Cross-Border Logistics (IF 5). Their status as core factors is not arbitrary— Fuzzy DEMATEL analysis confirms they occupy irreplaceable roles in the CBEC supply chain system:

First, from the perspective of prominence (D+R), these four factors rank among the core factors (IF 4: D+R=15.085, Rank 1; IF 5: D+R=14.799, rank 2; IF 2: D+R=14.290, rank 4; IF 1: D+R=14.159, rank 5). Their high (D+R) values mean they are not only influential in driving other factors but also deeply connected to the system's overall functionality—weakness in any one of them would cripple the entire resilience framework.

Second, in terms of causal role (D-R value), all four are classified as cause factors (D-R > 0), with varying degrees of driving power: IF 4 (D-R=0.814), IF 5 (D-R=0.498), IF 2 (D-R=0.304), and IF 1 (D-R=0.236). As cause factors, their optimization can proactively trigger ripple effects on effect factors.

Four key factors collectively enhance the resilience of CBEC supply chains. Government Support (IF4) offers institutional safeguards—such as policy incentives and emergency funding—to mitigate macro-level risks including trade barriers and geopolitical uncertainties. Cross-Border Logistics (IF5) enhances the efficiency of the ‘physical flow’ of goods through measures such as streamlined customs clearance and stable transportation, thereby reducing operational delays. Information Sharing (IF2) facilitates transparent ‘data flow’ by enabling mechanisms such as real-time shipment tracking and demand forecasting, which help to alleviate information asymmetry. Finally, Agility in the Supply Chain (IF1) strengthens the system’s ‘adaptability’ by supporting practices such as rapid supplier switching and dynamic inventory adjustment, thus improving responsiveness to sudden disruptions.

They do not operate in isolation but rather function as an organic, synergistic system that holistically strengthens the supply chain's ability to confront uncertainties, withstand disruptions, and rapidly recover—spanning from the macro policy environment to micro-level operational execution. To more clearly elaborate on the core role of each factor, their specific influences and functions are presented in Table 19.

Table 19 The Influence and Resilience Roles of the Four Core Factors in the CBEC Supply Chain

Factor	Influence in the Supply Chain	Role in Enhancing Resilience
Government Support	Shapes policy frameworks (e.g., customs regulations, tax incentives) and infrastructure investments; reduce administrative barriers and uncertainty in cross-border transactions.	Acts as a foundational driver by enabling stable operational environments, facilitating emergency coordination, and mobilizing resources to mitigate disruptions (e.g., funding resilience initiatives).
Cross-Border Logistics	Determines the efficiency, reliability, and cost of transporting goods across borders; directly impacts delivery timelines, inventory turnover, and responsiveness to demand fluctuations.	Enhances the supply chain’s ability to adapt to disruptions (e.g., delays, capacity shortages) through optimized routing, localized warehousing, and streamlined customs clearance.
Information Sharing	Improves visibility across supply chain nodes (suppliers, platforms, logistics providers); reduces information asymmetry and supports data-driven decision-making.	Enables proactive risk detection and coordinated responses to disruptions by ensuring timely access to critical data (e.g., demand forecasts, inventory levels, shipment statuses).
Supply Chain Agility	Reflects the speed and flexibility to adjust production, procurement, or distribution in response to unexpected changes (e.g., demand surges, supply shortages).	Enhances the ability to recover quickly from disruptions by reallocating resources, pivoting them to alternative suppliers, or modifying logistics plans to maintain continuity.

Effective Enhancing Pathways for CBEC Supply Chain Resilience Action Plans

To convert the targeted action plans—firmly anchored in the four core resilience factors of CBEC supply chains (Agility in Supply Chain (IF 1), Information Sharing (IF 2), Government Support (IF 4), and Cross-Border Logistics (IF 5))—into tangible, measurable improvements in resilience, the entire enhancement process must adhere to three Guiding principles: clear responsibility delineation, phased execution prioritization, and time-bound planning. The visualization of foundational principles, as shown in Figure 25.

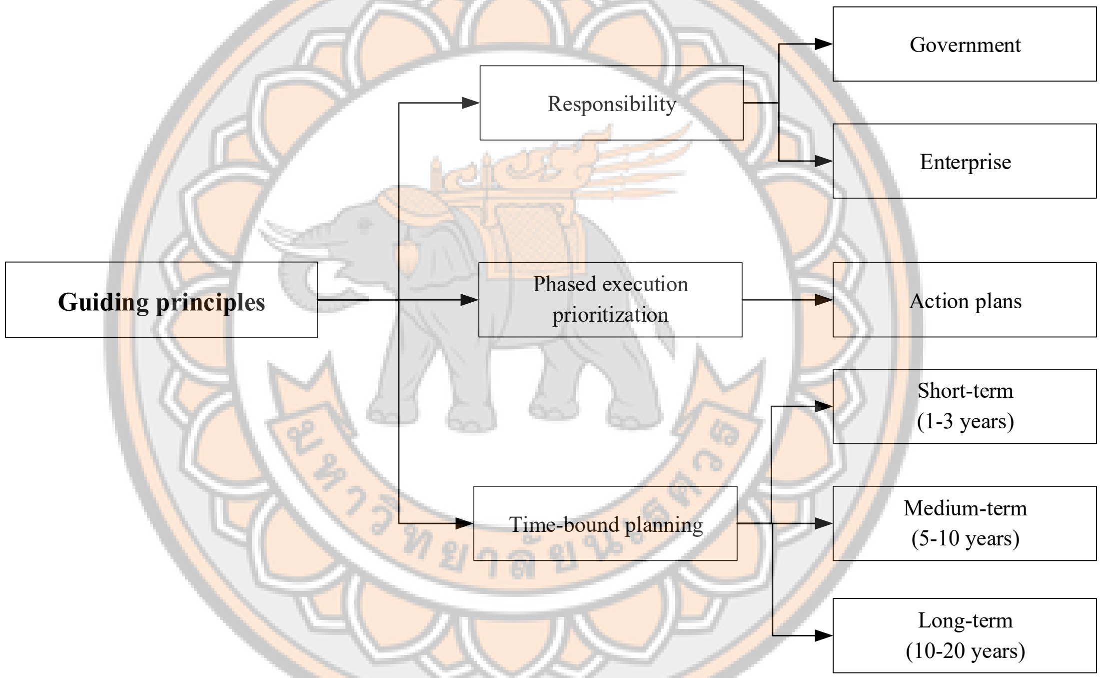


Figure 25 The Visualization of Guiding Principles

The resilience of CBEC supply chains is a shared responsibility, requiring coordination among governments, platforms, logistics providers, and suppliers, as no single stakeholder can achieve it alone. Implementation must first clarify who does what, why, and what they gain. For example, government focuses on regulatory reform, infrastructure investment, and crisis contingency planning, aiming to enhance economic growth by supporting resilient CBEC.

Attempting to implement all actions at once risks resource overload and stakeholder fatigue. Instead, a phased timeline—divided into short-term, medium-term, and long-term—balances "quick wins" with gradual, deep integration.

The division for CBEC supply chains into short-term, medium-term, and long-term timeframes is not arbitrary; it is rooted in three core bases: policy implementation logic, project maturity cycles, and industry development needs—all aligned with the practical characteristics of CBEC, which is highly dependent on infrastructure, policy coordination, and technological adaptation. Short-term: Explicitly defined as 1-3 years. It prioritizes "immediate execution" and requires annual progress reviews to adjust resource allocation promptly. Medium-term: Set as 5-10 years. It builds on short-term achievements. Long-term: Specified as 10-20 years. This timeframe focuses on "strategic layout".

These ways address the inherent complexity of CBEC ecosystems while ensuring every step directly aligns with the resilience goals validated by prior Fuzzy DEMATEL analysis.

Each core factor requires tailored actions that leverage the strengths of its lead stakeholders. Below are detailed, actionable steps for each factor, aligned with the three-phase timeline and above.

Government Support

Government support is the foundation for building a resilient supply chain, primarily providing enablement and guarantees through funding, data, and crisis coordination.

Firstly, the "Multilateral Resilience Fund Initiative" is a core short-term (1-3 years) plan. Government needs to lead negotiations with major trading partners to establish the fund's charter, contribution models, and governance rules, and set up transparent and fair application and audit processes to ensure funds are used to support enterprise (especially SME) resilience projects, such as supply chain diversification and technology upgrades. Enterprises should provide input through industry associations to ensure the fund's design meets practical needs, and proactively apply for funds, effectively implement projects, and report results. The goal of this initiative is to quickly mobilize capital and inject risk resistance capabilities into the industry.

The mid-term (5-10 years) focus is on "Mandating SME Access to Public Data Platforms". The core duty of the government is to build user-friendly, API-based public data platforms (e.g., for customs status, port congestion data), and legislate large logistics providers and port operators to share data in standardized formats, while providing subsidies for SMEs to access these platforms, breaking their "information silo" dilemma. On the enterprise side, large enterprises must comply with data sharing regulations, while SMEs need to actively utilize these resources to optimize their decision-making. This aims to democratize supply chain information and comprehensively enhance the visibility and planning capabilities of SMEs.

The long-term (10-20 years) vision is to establish the "Critical Node Emergency Coordination Initiative". The government must lead the mapping of the entire CBEC supply chain to identify single points of failure (e.g., ports, hubs) and form a standing joint task force comprising government and industry experts to pre-establish contingency protocols, empowered to activate them (e.g., cargo rerouting, temporary regulatory exemptions) during major disruptions. Enterprises need to provide operational data and expertise to support the mapping and strictly adhere to and utilize the emergency protocols during crises. This mechanism aims to achieve a leap from passive response to proactive prediction and collaborative response.

Agility in Supply Chain

Agility requires the supply chain to have the ability to adjust dynamically and respond quickly to changes. Its enhancement path progresses from technical optimization to networked collaboration.

In the short term (1-3 years), significant results can be achieved quickly through "AI Dynamic Warehouse Allocation". The government should encourage technology adoption by funding relevant research and development algorithms and providing tax incentives. Enterprises (especially large platforms and logistics providers) need to invest in and deploy AI systems that analyze demand, transportation costs, and lead times in real-time to dynamically decide the optimal storage locations for inventory (e.g., bonded warehouses, overseas warehouses), achieving the optimal balance between cost and speed. This leverages technology to unlock agility potential within the existing network.

In the medium term (5-10 years), there is a need to build "Emergency Logistics Corridors". The government's role is to establish pre-cleared, prioritized emergency logistics channels and air corridors with partner countries through diplomatic negotiations, providing security guarantees and simplified regulations. Enterprises need to subscribe to use these corridors by paying membership fees or premiums, funding their maintenance, and prioritizing their use during emergencies, while also participating in regular drills to test their reliability. This builds predictable resilient channels within the physical infrastructure.

The ultimate long-term (10-20 years) form is the creation of a "Shared Manufacturing Capacity Platform". The government needs to act as a catalyst to promote the establishment of a neutral and secure industrial internet platform and develop clear legal frameworks to address quality control and liability issues in sharing. Enterprises enable manufacturers to list idle capacity, allowing e-commerce platforms and brands to quickly source and match emergency production capacity on this platform when facing supply shortages. This will create a highly flexible, demand-responsive distributed manufacturing network, fundamentally enhancing the agility of the entire ecosystem.

Information Sharing

Information is the lifeblood of modern supply chains. The level of sharing will gradually evolve from data aggregation to trusted automation under privacy protection.

The short-term (1-3 years) goal is to build the Public Platform for "CBEC Supply Chain Data Brain". The government is the builder and operator of the platform, responsible for aggregating massive amounts of anonymized data from enterprises, ports, and logistics, providing macro insights, early warnings, and performance benchmark reports back to the industry through analysis. The responsibility of Enterprises is to contribute anonymized data and actively use the insights published by the platform for strategic planning. This aims to create industry-level situational awareness.

The mid-term (5-10 years) focus is on establishing the "Supply-Demand Matching AI Aggregation Platform". The government's role is to facilitate platform development and ensure the fairness and non-monopolistic nature of its AI algorithms. Enterprises need to allow the AI platform limited access to their inventory and demand forecast data and rely on its powerful matching capabilities to automatically connect suppliers with excess inventory to buyers in urgent need of goods. This will massively optimize network resource allocation and reduce the bullwhip effect and stockouts.

In the long term (10-20 years), the "Blockchain Smart Contract + Privacy Computing" Sharing Mechanism will be promoted. The government needs to set national-level technical and protocol standards and pioneer pilot projects in scenarios such as customs clearance and tax refunds. Enterprises need to invest in compatible IT infrastructure, actively participate in blockchain networks, and use smart contracts to automate processes based on event triggers (e.g., automatic payment triggered by GPS proof of delivery). This will achieve frictionless automated transactions under absolute trust and privacy security, fundamentally transforming supply chain collaboration models.

Cross - Border Logistics

Cross-border logistics is the physical backbone of CBEC. Its evolution is towards prepositioning, greening, and intellectualization.

The short-term (1-3 years) breakthrough is building a network of "Localized Warehouses". The government needs to promote mutual recognition of bonded warehouse regulations with key market countries through international negotiations and simplify regulatory procedures for transferring goods between different warehouses. Enterprises (platforms, sellers, logistics providers) need to invest in or lease numerous small, prepositioned satellite warehouses in key target markets to store best-selling items for extreme last-mile delivery speed.

In the medium term (5-10 years), there is a need to establish "Green Customs Priority Channels". The government should design a certification system establishing "green channels" for goods that meet strict sustainable development standards (e.g., carbon-neutral transportation, eco-friendly packaging), providing tangible incentives such as fast-track clearance, reduced inspections, and fee reductions. To obtain certification, Enterprises need to proactively adopt green packaging and choose environmentally friendly logistics partners and use this channel to enhance supply chain efficiency and brand image. This integrates resilience development with green development.

The long-term (10-20 years) vision is to achieve "Smart Port Automation". The government needs to invest in upgrading public port infrastructure and remove legal obstacles for fully automated operations (e.g., regulations for autonomous driving within port areas). Port operators and technology companies need to vigorously develop and deploy AI-controlled cranes, autonomous vehicles, and IoT devices. Logistics companies need to deeply integrate their systems with the port's operating system. The goal is to transform ports from potential bottlenecks into efficient, predictive, unmanned logistics hubs with high throughput.

In summary, this action plan is an interconnected and progressively layered whole. Only with clear responsibilities and collaborative efforts between the government and enterprises, following the implementation path of short, medium, and long-term phases, can the blueprint be transformed into reality, jointly building a new generation of CBEC supply chain system that is resilient, efficient, and forward-looking. Summary of action plans, as shown in Table 20.

Table 20 Plans for Enchaining the CBEC Supply Chain Resilience

Core factors	Plans	Responsibility	Time frames of planning
Government Support	Multilateral Resilience Fund Initiative	Governance, Enterprise	Short-term plan (1-3 years)
	Mandate SME Access to Public Data Platforms	Governance, Enterprise	Middle -term plan (5-10 years)
	Critical Node Emergency Coordination Initiative	Governance, Enterprise	Long-term plan (10-20 years)
Agility in Supply Chain	AI Dynamic Warehouse Allocation	Governance, Enterprise	Short-term plan (1-3 years)
	Emergency Logistics Corridors	Governance, Enterprise	Middle -term plan (5-10 years)
	Shared Manufacturing Capacity Platform	Governance, Enterprise	Long-term plan (10-20 years)
Information Sharing	Building the "cross-border e-commerce supply chain data brain" public platform	Governance, Enterprise	Short-term plan (1-3 years)
	Establishment of "Supply and Demand Matching AI Aggregation Platform"	Governance, Enterprise	Middle -term plan (5-10 years)
	Promote "Blockchain Smart Contract + Privacy Computing" sharing mechanism	Governance, Enterprise	Long-term plan (10-20 years)
Cross-Border Logistics	Localized Warehouses	Governance, Enterprise	Short-term plan (1-3 years)
	Green Customs Priority Channel	Governance, Enterprise	Middle -term plan (5-10 years)
	Smart Port Automation	Governance, Enterprise	Long-term plan (10-20 years)

CHAPTER VI
CONCLUSION AND RECOMMENDATIONS

This chapter synthesizes conclusions derived from the study's analysis of factors influencing China's CBEC supply chain resilience and proposes actionable recommendations based on the findings.

Conclusion

This paper aims to achieve three objectives: identifying the influencing factors that impact the resilience of the CBEC supply chain, then systematically analyzing the interdependencies among these factors, and proposing a plan to increase the resilience of the CBEC supply chain.

Identifying the influencing factors that impact the resilience of the CBEC supply chain

To achieve objective one, the paper first conducted a systematic literature review to identify 16 potential influencing factors documented in existing studies. Then empirically validated through structured interviews with experts. The analysis ultimately confirmed 10 influencing factors, ranked as follows: Agility in the Supply Chain, Information Sharing, Inventory Management, Visibility in the Supply Chain, Cross Border Logistics, Government Support, Pay and Credit, Trust with partners, Geographic Distribution, Risk Management Culture.

The interdependencies among these factors

To address the second objective of analyzing the interdependencies among the validated influencing factors on CBEC supply chain resilience, Fuzzy DEMATEL is employed. This hybrid method combines fuzzy logic to handle ambiguity in expert judgments with DEMATEL's causal mapping capabilities, enabling a systematic evaluation of complex cause-effect relationships. Five experts independently assessed the initial pairwise influence levels among the validated influencing factors. A cause-effect diagram, constructed using prominence (D+R) and net effect (D-R) values, clearly illustrates the interrelationships among these factors. This paper concludes that cross-border logistics, information sharing, government support, agility in the supply chain, risk management culture and geographic distribution as cause factors. Four factors—inventory management, pay and credit system, visibility in the supply chain, and trust with partners are considered effect factors.

The diagram is segmented into four quadrants, categorizing factors as core factors, driving factors, independent factors, and impact factors. Core Factors, such as Agility in Supply Chain (IF 1), Information Sharing (IF 2), government support (IF 4), Cross-Border Logistics (IF 5). Driving factors, including geographic distribution (IF 9) and risk management capability (IF 10). Inventory management (IF 3) and visibility in supply chain (IF 6) are independent factors. Impact factors, which include trust with partners (IF 8) and the pay and credit system (IF 7).

Plans for enchaining the CBEC supply chain resilience

Before proposing actionable plans to strengthen the (CBEC) supply chain supply chain resilience, it is critical to anchor interventions focus on four core factors (QI Quadrant) that underpin systemic resilience: Agility in supply chain, Information Sharing, Government Support, and Cross-Border Logistics.

Considering these core determinants, we can then propose actionable plans, clarify the main entities involved, and define the time frame for implementation, as shown in Table 20.

Recommendations

Future research could expand the scope by comparing resilience factors across different regions, business models (such as B2B and B2C), or market scales.

Theoretical contributions of this study lie in enriching the existing body of knowledge on CBEC supply chain resilience. By applying the Fuzzy DEMATEL model, it offers a novel perspective on quantifying the complex relationships among influencing factors, thereby advancing the methodological toolkit for researchers in this field. Practically, the findings provide actionable insights for various stakeholders. Policy makers are advised to prioritize the establishment of stable and supportive cross-border policies to create a conducive environment for CBEC development. Enterprises should invest in digital technologies and cultivate flexible supplier networks to improve their ability to respond to uncertainties. Additionally, collaborative efforts between different sectors are crucial for aligning strategies and resources to enhance the overall resilience of the CBEC supply chain.

It is important to acknowledge the limitations of this study. The fuzzy DEMATEL approach relies on experts' fuzzy linguistic evaluations of inter-factor influence intensities, which are susceptible to subjective biases stemming from individual cognitive. Future studies should integrate machine learning or system dynamics with DEMATEL to capture time-sensitive shifts in factor relationships (e.g., sudden policy changes like carbon tariffs).

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APPENDIX

APPENDIX A

Questionnaires of Identifying factors

Title: Analysis of Factors Influencing Cross Border E-Commerce Supply Chain Resilience Based on the Fuzzy-DEMATEL

The questionnaire was produced by Xinwei Pan, a master student from the Faculty of Logistics and Digital Supply Chain, at Naresuan University. The aim is to explore the influencing factors that affect the resilience of cross-border e-commerce supply chains. Cross-border e-commerce was defined as consumers buying online from merchants in other countries and jurisdictions. Supply Chain Resilience refers to the supply chain that can recover a depleted state or evolve into an ideal state as soon as possible in the face of external shocks and internal changes. The various nodes of the supply chain are closely connected, and once they are affected by slight factors, the supply chain may be interrupted. So, it is necessary to analyse the factors which affect Cross-border e-commerce supply chain resilience.

The volume survey is purely for the completion of the personal dissertation and is not used for any other purpose. The data is for research purposes only and will not have any impact. For any respondents, please answer the questionnaire based on the most realistic situation.

Section I Basic Information

Section II Details the factors affecting Cross border e commerce supply chain resilience from respondents.

Analysis of Factors Influencing Cross Border E-Commerce Supply Chain Resilience Based on the Fuzzy-DEMATEL

Section I General information

Clarification: Please write a ✓ sign-in ☐ for the best matches your reality.

1.Highest academic qualification

☐ 1. Bachelor ☐ 2. Masters

☐ 3. Doctor of Philosophy ☐ 4. Other (please specify) ____

2. Years of working experience

☐ 1. 25 years or more ☐ 2. 21- or 25-years

☐ 3. 11 or 20 years ☐ 4. 10 years

3. Position belongs to: ____

Section II Details the factors affecting Cross border e commerce supply chain resilience from respondents

Clarification: Please write a ✓ sign ☐ for each item that best matches your feedback. Each channel shows the level of need.

+1 = Essential 0 = Useful but not essential -1 = Not necessary

Factor	Definition	Essential (+1)	Useful but not essential (0)	Not necessary (-1)
Cross Border Logistics	Management of the movement and coordination of goods across international borders, ensuring efficient and compliant operations.	☐	☐	☐
Information Sharing	The exchange of data and insights among supply chain partners to enhance transparency and decision-making.	☐	☐	☐
Inventory Management	Control of inventory levels, ordering, and usage to meet customer demand efficiently.	☐	☐	☐
Customer Demand Variability	Fluctuations in customer purchasing behavior, affecting supply chain planning and inventory needs.	☐	☐	☐
Visibility in Supply Chain	The ability to monitor goods and information across the supply chain in real-time for better responsiveness and risk reduction.	☐	☐	☐
Agility in Supply Chain	The capacity of the supply chain to quickly adapt to unexpected changes or disruptions.	☐	☐	☐

Government Support	Assistance provided by governmental entities, such as subsidies, policy support, or infrastructure development.	☐	☐	☐
Pay and Credit System	Financial mechanisms that support transactions between supply chain partners, including credit terms and payment systems.	☐	☐	☐
Trust with Partner	The level of confidence and reliability established between supply chain partners, promoting cooperation and risk reduction.	☐	☐	☐
Geographic Distribution	The spatial placement of supply chain facilities and partners, influencing efficiency, costs, and responsiveness.	☐	☐	☐
Risk Management Culture	It systematically internalized values, behavioral norms, and institutional frameworks within an organization, enacted through a tri-level mechanism of leadership commitment, employee engagement, and cross-functional collaboration.	☐	☐	☐
Cross Border Logistics Infrastructure	Physical and technological facilities (e.g., warehouses,	☐	☐	☐

	transportation networks, IT systems) supporting cross-border logistics.			
AI (Artificial Intelligence)	Use of machine learning and data analytics to automate processes, optimize decision-making, and predict patterns in the supply chain.	☐	☐	☐
Customs Clearance	The official procedures for moving goods through customs to comply with regulatory requirements for import/export.	☐	☐	☐
Cybersecurity Measures	Security practices to protect digital information and systems within the supply chain from cyber threats.	☐	☐	☐
Staff Training and Development	Programs aimed at improving employee skills and knowledge to enhance efficiency and adaptability in supply chain operations.	☐	☐	☐

Other requirement

Except for the above factors, what factor(s) do you think can be regarded as factors to affect Cross border e commerce supply chain resilience?

....
....
....

Thank you for your participation and cooperation in completing the survey.

APPENDIX B

Questionnaires

Title: Analysis of Factors Influencing Cross-Border E-Commerce Supply Chain Resilience Based on the Fuzzy-DEMATEL

The questionnaire was produced by Xinwei Pan, a master student from the Faculty of Logistics and Digital Supply Chain, at Naresuan University. The aim is to explore the releationship of influencing factors that affect the resilience of cross-border e-commerce supply chains.

The volume survey is purely for the completion of the personal dissertation and is not used for any other purpose. The data is for research purposes only and will not have any impact. For any respondents, please answer the questionnaire based on the most realistic situation.

Section I Basic Information

Section II The interrelationships among influencing factors that impact the resilience of the CBEC supply chain

Analysis of Factors Influencing Cross-Border E-Commerce Supply Chain Resilience Based on the Fuzzy-DEMATEL

Section I General information

Clarification: Please write a ✓sign-in ☐ for the best matches your reality.

1. Highest academic qualification

☐ 1. Bachelor ☐ 2. Masters

☐ 3. Doctor of Philosophy ☐ 4. Other (please specify) ____

2. Years of working experience

☐ 1. 25 years or more ☐ 2. 21- or 25-years

☐ 3. 11 or 20 years ☐ 4. 10 years

3. Position belongs to: ____

Section II The interrelationships among influencing factors that impact the resilience of the CBEC supply chain

Clarification: Please write a subitable number sign ☐ for each item that best matches your feedback. Each channel shows the level of need:

4 = Agree that X_i has a very high influence relationship with X_j extent

3 = Agree that X_i has a high-influence relationship with X_j

2 = Agree that X_i has a little influence relationship with X_j extent

1 = Agree that X_i has a very low-influence relationship with X_j extent

0= Agree that X_i has no influence relationship with X_j extent

Note：

Code	**Influencing Factors**	Code	**Influencing Factors**
IF 1	Agility in Supply chain	IF 6	Government Support
IF 2	Information Sharing	IF 7	Pay and Credit System
IF 3	Inventory Management	IF 8	Trust with partner
IF 4	Visibility in Supply Chain	IF 9	Geographic Distribution
IF 5	Cross Border Logistics	IF 10	Risk Management Culture

j \ *i*	IF 1	IF 2	IF 3	IF 4	IF 5	IF 6	IF 7	IF 8	IF 9	IF 10
IF 1	-	☐	☐	☐	☐	☐	☐	☐	☐	☐
IF 2	☐	-	☐	☐	☐	☐	☐	☐	☐	☐
IF 3	☐	☐	-	☐	☐	☐	☐	☐	☐	☐
IF 4	☐	☐	☐	-	☐	☐	☐	☐	☐	☐
IF 5	☐	☐	☐	☐	-	☐	☐	☐	☐	☐
IF 6	☐	☐	☐	☐	☐	-	☐	☐	☐	☐
IF 7	☐	☐	☐	☐	☐	☐	-	☐	☐	☐
IF 8	☐	☐	☐	☐	☐	☐	☐	-	☐	☐
IF 9	☐	☐	☐	☐	☐	☐	☐	☐	-	☐
IF 10	☐	☐	☐	☐	☐	☐	☐	☐	☐	-

Thank you for your participation and cooperation in completing the survey.