A Meta-Analysis of Eyeglass Manufacturing Supply Chain Efficiency for Protection Global Crisis Impacted

Sarot Ake Kankoon[1]

Abstract

Global crises occurring within a period of 5 years (2019-2023). The coronavirus disease (COVID-19) has a huge impact throughout the world, the Ukraine-Russia war impacted with transport to close the country's airspace, Red Sea closed shipping lanes in Suez Canal. Eyeglass lens manufacturing is one of the industries most affected by disruptions to the global supply chain. Shortage of raw materials for producing eyeglass lenses, loss of manpower to support production, delayed delivery of machinery and a shortage of eyeglass lenses for people with vision problems. The above-mentioned problems directly affect the health of those with vision problems. This has safety implications and can endanger the lives of people with vision problems. Therefore, the first-time studies and methods of strengthening the supply chain to being studied. For warehouse management services for eyeglass lens production. This article has selected a systematic review and meta-analysis (PRISMA) and a focus group of eyeglass lens business experts. This requires inventory management in a global crisis. Considered together with suppliers, manufacturers, distributors. and hospital and eye care service providers under ISO 13485: Medical equipment and risk management new model of eyeglass lens inventory management to prevent the global crisis impacting wasted eyeglass lens supply and support the needs of hospital and eye care providers. This study provides a meta-analysis of eyeglass manufacturing supply chain performance. To prevent the effects of global crises. This research aims to find an efficient inventory control model for the eyeglasses supply chain. To protect against glasses shortages during the global crisis and support social sustainability.

Keywords: Risk Management, Eyeglass, Inventory Management, Global Crisis, Supply Chain

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การวิเคราะห์อภิมานของประสิทธิภาพห่วงโซ่อุปทานการผลิตแว่นตา เพื่อป้องกันผลกระทบจากวิกฤตทั่วโลก

Sarot Ake Kankoon[2]

บทคัดย่อ

วิกฤตการณ์ระดับโลกที่เกิดขึ้นภายในระยะเวลา 5 ปี (พ.ศ. 2562-2566) การระบาดของโรคติดเชื้อไวรัสโคโรนา (โควิด-19) ส่งผลกระทบอย่างใหญ่หลวงไปทั่วโลก, สงครามยูเครน-รัสเซีย ส่งผลให้กรมขนส่งไม่สามารถปิดน่านฟ้าของประเทศได้, การปิดเส้นทางเดินเรือในทะเลแดงที่เชื่อมต่อกับคลองสุเอซ โรงงานผลิตเลนส์แว่นตาถือเป็นอุตสาหกรรมหนึ่งที่ได้รับผลกระทบจากการหยุดชะงักของห่วงโซ่อุปทานทั่วโลก การขาดแคลนวัตถุดิบในการผลิตเลนส์แว่นตา, การสูญเสียกำลังคนเพื่อรองรับการผลิต, การส่งมอบเครื่องจักรล่าช้า และการขาดแคลนเลนส์แว่นตาสำหรับผู้ที่มีปัญหาด้านการมองเห็น ปัญหาที่กล่าวมาข้างต้นส่งผลโดยตรงต่อสุขภาพกับผู้ที่มีปัญหาการมองเห็น ซึ่งมีผลกระทบด้านความปลอดภัยและอาจก่อให้เกิดอันตรายต่อชีวิตของผู้ที่มีปัญหาการมองเห็นได้ ดังนั้น จึงเป็นครั้งแรกที่มีการศึกษาและเรียนรู้วิธีการเสริมสร้างห่วงโซ่อุปทาน สำหรับบริการการจัดการคลังสินค้าของการผลิตเลนส์แว่นตา บทความนี้ได้เลือกการทบทวนอย่างเป็นระบบและการวิเคราะห์เมตาดาต้า (PRISMA) และการสนทนากลุ่มผู้เชี่ยวชาญธุรกิจเลนส์แว่นตา ซึ่งจำเป็นต้องดำเนินการบริหารจัดการสินค้าคงคลังในภาวะวิกฤติโลก โดยพิจารณาร่วมกับซัพพลายเออร์, ผู้ผลิต, ผู้จัดจำหน่าย และผู้ให้บริการโรงพยาบาลและการดูแลดวงตา ภายใต้ ISO 13485 : อุปกรณ์การแพทย์ และการบริหารความเสี่ยง รูปแบบใหม่ของการจัดการสินค้าคงคลังเลนส์แว่นตาเพื่อป้องกันวิกฤติทั่วโลกที่ส่งผลกระทบต่ออุปทานเลนส์แว่นตาที่สูญเสียและสนับสนุนความต้องการของผู้ให้บริการโรงพยาบาลและการดูแลสุขภาพตา การศึกษานี้มีการวิเคราะห์อภิมานของประสิทธิภาพห่วงโซ่อุปทานการผลิตแว่นตา เพื่อป้องกันผลกระทบจากวิกฤตทั่วโลก โดยงานวิจัยนี้มีเป้าหมายในการค้นหาโมเดลการควบคุมสินค้าคงคลังให้มีประสิทธิภาพของห่วงโซ่อุปทานของแว่นตา เพื่อปกป้องกันการขาดแคลนแว่นตาในช่วงวิกฤตโลก และสนับสนุนความยั่งยืนทางสังคม

คำสำคัญ: การบริหารความเสี่ยง, เลนส์แว่นตา, การบริหารสินค้าคงคลัง, วิกฤตทั่วโลก, ห่วงโซ่อุปทาน

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Introduction

Since 2019-2023, The global crisis has impacted with overall industry and manufacturing supply chain the world. The Eyeglass industry is one that has been affected by supply chain disruption which it's impacted with shortages of critical eyeglass lens for support with customer demand insufficiency.

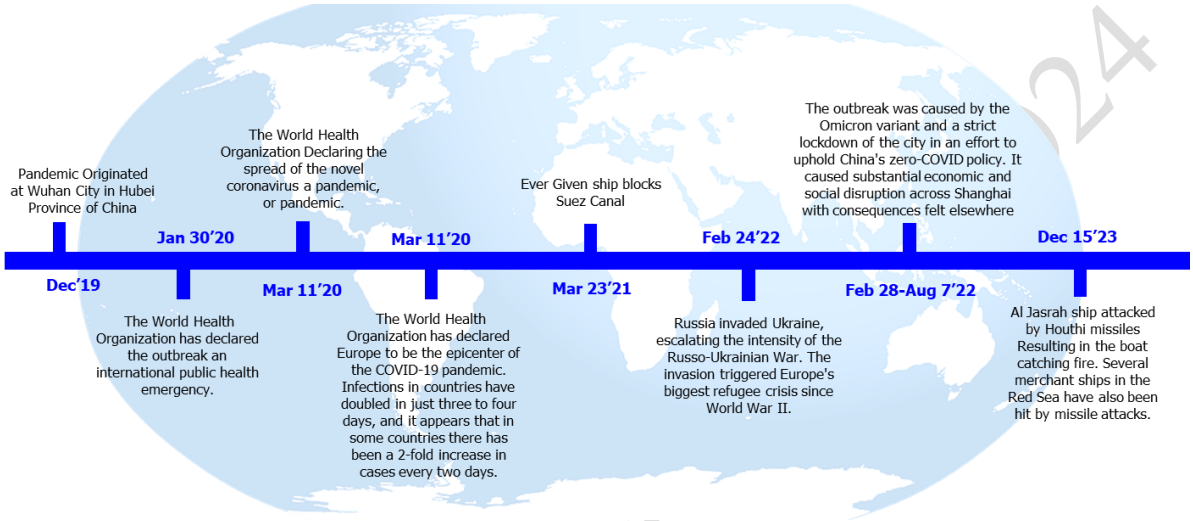

Figure 1: Global crisis in FY 2019 to 2023 period

Coronavirus disease 2019 or COVID-19 disease (COVID-19) is caused by infection with a new strain of coronavirus. Named Severe Acute Respiratory Syndrome Coronavirus 2 or SARS-CoV-2, December 30, 2019, Wuhan City Public Health Office Hubei Province has issued an official announcement that Found a group of patients with pneumonia. Unknown cause, later known as COVID-19, related to Hua Nan market which is a trading market largest seafood in Wuhan and central China (Xu et al., 2020). The rapid outbreak of COVID-19 has become a global threat because every area of the world has been affected and has caused global impacts related to industrial supply chains and caused Disruption of global supply chains (Das, 2021).

The Ever Given is blocking the Suez Canal, an incident occurred on Tuesday, March 23, 2021. The container ship Ever Given is stuck in the Suez Canal in Egypt. The latter left a port in China and was headed to the Netherlands. The Suez Canal Authority (SCA) has stated the cause of the Ever Given's 'blockage' as the ship was passing through the Suez Canal on Tuesday. A sandstorm developed with winds over 40 knots (about 74 kilometers per hour) and reduced visibility. Until finally the boat lost control. The bow of the ship ran aground at kilometer 151, with the hull completely blocking the passage of the Suez Canal. The Suez Canal is a shipping route that accounts for approximately 12% of global shipping (Associated Press, 2024). This incident of a ship blocking the Suez Canal. The Eyeglass Lens industry used this route with Supplies Europe country to Eyeglass Lens manufacturing in Asia country.

The Russian-Ukrainian Conflict: Impact on DACHSER's Global Air and Sea Transport Operations. Reservations for shipments originating or destined in Ukraine are suspended until further notice. We are also no longer able to accept reservations for rail transportation between Asia and Europe. The same suspension of bookings also applies to trucking between Asia and Europe. If the shipment is through Russia, Belarus or Ukraine, the reason we take these measures is because we cannot guarantee the safety of our customers' shipments passing through these countries. In addition to these specific measures, We also foresee additional implications for our operations. Conflict regions in each country involved in such conflicts are very important to the international oil and energy market.

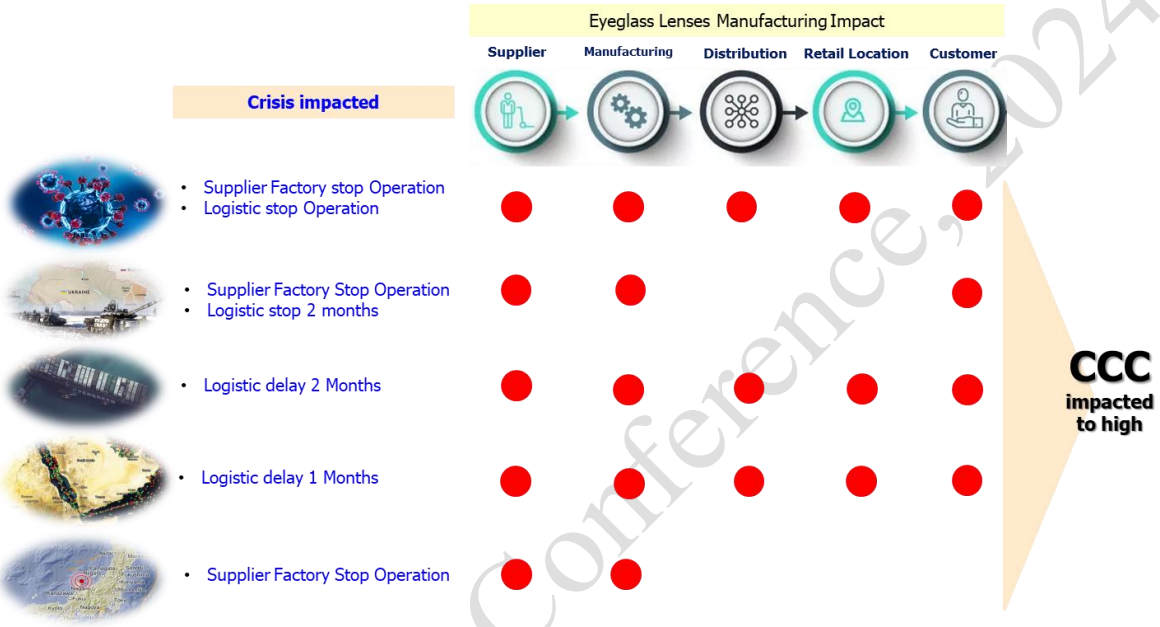

Figure 2: Global crisis impacted with Eyeglass Lens Manufacturing Impact

The supply chain of the eyeglass lens business involves a variety of activities and operations. This is shown in Figure 3 Eyeglass lens supply chain management involves managing Resources and materials used in the process as well as delivering eyeglasses products to vision care providers and patients with refractive errors patients. The supply chain with Eyeglass lens business, It is a process that involves medical equipment. and medical services in the form of physical goods and information transmitted through various stakeholders. Stakeholders in the eyeglass lens supply chain include suppliers, manufacturers/importers. Hospital/Clinic Eye care product provider Group purchasing organization and regulatory agencies (Proctor. et al., 2022).

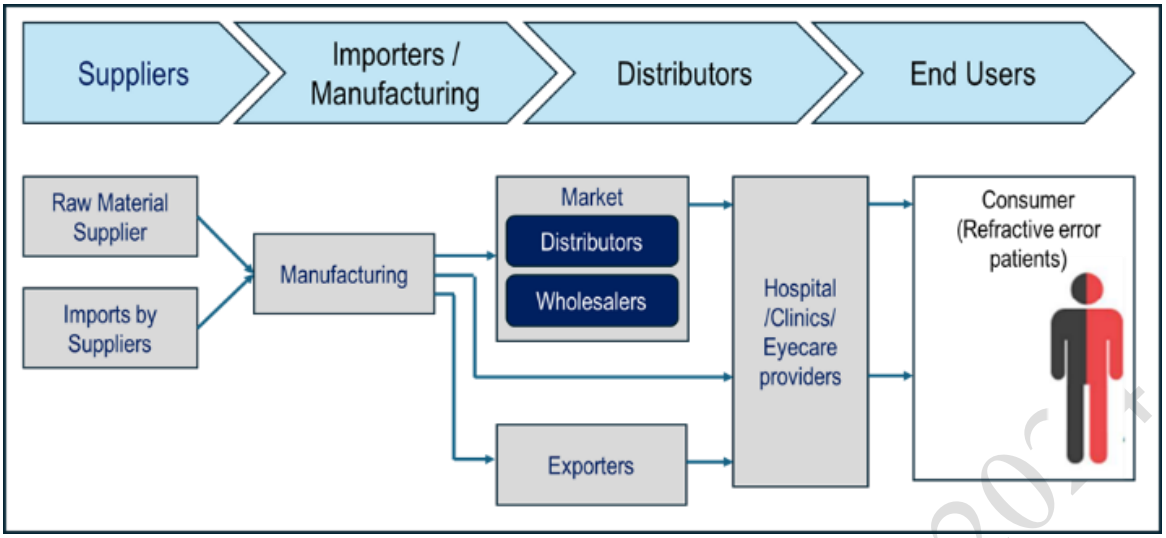

Figure 3: Eyeglass Lens Supply Chain Manufacturing Management

This paper focused on finding out the impact of the global crisis on the eyeglass lens industry with transportation to impacted with customers and the global supply chain that is affected by the global crisis with eyeglass lens business operation. We can know with some degree of accuracy all the impacts related to the supply chain of the eyeglasses business once the crisis is over or under control. In such a way that there is a degree of uncertainty and instability in the transportation system. Anyhow operating the eyeglass lens business to face the logistics costs increasing from global crisis. In addition to that, there is a shortage of raw materials to support the production process. This will affect production costs.

For a competitive advantage in the eyeglass lens industry, the manufacturer produces high quality eyeglass lenses and meets customer demand in all requirements. In addition, transportation process and delays in the production process delays to impacted with a high cost. It can also become an added value in providing services to customers (Simbolon & Santoso, 2021).

At present, competition in the eyeglass lens industry is extremely high from customer needs which Manufacturers must produce quality lenses that meet customer expectations. In addition, manufacturing must be the performance with deliver products on time and a short production process to increase the value of services to customers (Simbolon & Santoso, 2021). Anyhow to the low possibility of mass production, the complexity with production capacity increasing problem with delivery service a long time from customer expectation or a contract from the moment of ordering to the production and delivery of products to the optical store (Gyulai et al., 2018). The customers tend to desire shorter manufacturing and delivery times as Eyeglasses Lens are very important to aid people with visual impairment (Simbolon & Santoso, 2021).

Highly unique products A wide range of options will be offered covering most of the important features. glasses lens case The customer orders products based on available catalog offers made from standard components. This process is unique to high variability in production and cost. Similar products are produced but they have different parameters. Basic parameters that describe corrective lenses is the power of the lens Cylinder power and axis and the type of coating. The main optical characteristics of the lenses require the customer to rely only on a complex initial manufacturing process (Markou & Corsten, 2021).

Lens prices also reflect the challenge of determining appropriate order quantities. and the best production volume to match safety stock levels with customer demand, global supply chain performance focuses on costs and profitability. There is a lot of literatureม it includes a variety of models for effective inventory management under various business conditions (Rajput et al, 2022). Business managers consider the interconnectivity of risks: holding costs are going up, transportation and mode shipment booking ships is becoming more and more difficult. There are port delays, sometimes two or three weeks. That in turn is driving up safety stock, and fuel surcharges are driving up transportation costs. .

This study therefore focuses on eyeglass lens inventory management during a global crisis. This research is expected to find factors affecting warehouse management and the best inventory control model for eyeglass lenses during the global crisis. Furthermore, the results of the study will support eyeglass lens manufacturing to match with customer demand and minimize holding inventory cost in providing the best solution to manage an eyeglass lens inventory. Specifically, this study focused on the inventory management aspects that are vital for the performance of eyeglass lens in terms of cost, quality, and patient responsiveness in manufacturing: inventory level control and minimize with warehouse cost.

Literature Review

- Inventory Management

Inventory management is an important part of an organization's cost management decisions, such as activities that must be carried out according to inventory management policies and steps in managing inventory to ensure that each product item has the right quantity and is sufficient to meet customer needs. Inventory management important part of the supply chain system, holding inventory cost to must be taken as an important factor in the production costs of manufacturing order to increase their competitive advantage. (Hasbullah et al., 2021; Singh & Verma, 2018). Available physical space, Products Quality, Returning products from Damaged products and Demand forecasting. Inventory is essential in manufacturing production costs (Hasbullah & Santoso, 2020). The customer demand fluctuations is a risk of forecasts that do not match with actual demand, thus affecting changes in production planning that have continued until now (Shao et al., 2021). Proper inventory requires determining the amount of inventory required during the grace period to meet customer demand (Godichaud & Amodeo, 2019).The main key point with inventory management is to cover topic many such as Scheduling replenishment inventory, Production costs, Warehouse Cost and Inventory holding costs Asset management, Inventory forecast, Inventory valuation, Future inventory price forecasts, Physical inventory, Storing goods in warehouses creates certain risks that the company bears because of the stock (Rossit et al., 2019). Inventory management has a positive influence on a company's growth. This has led to the importance that the import market and business environment in Vietnam to have not yet stimulated good economic activities. Therefore, they have leveraged and created additional financial resources such as borrowing to pool external resources. together (Park et al., 2020)

- Warehouse Management

Warehousing is one of the fundamental processes in supply chain management, according to important part of integration in all activities of the supply chain. (Hamdy et al. 2022). Therefore, it is an essential part of the product's operation as it contributes to achieving proper and continuous operation of the production process until the distribution process according to (Torbacki et al. 2019). New roles for warehouses have been discovered over the past few years. It can make processes in the entire chain better integrated to not only storing products. It helps to see the service better with this function this makes. It is possible to avoid overstocking products throughout the supply chain. Therefore, its digitization and use in the exchange of information between partners to real-time inventory levels in particular important. As a result, Industry 4.0 digital solutions are quickly finding their way into internal logistics processes and create intelligent warehouse design Also known as Warehouse 4.0. These warehouses are designed and run with the fundamental principles of I4.0 including interoperability, virtualization, decentralization, real-time, service orientation, modularity and the ability to configure warehouse capacity (Zoubek et al., 2021). Currently warehouse management meets the demand from customers for managing all warehouse processes efficiently and design dynamic warehouse facilities that are easily accessible (Khan et al., 2022).

- Economic Order Quantity (EOQ)

The business operations effective a company depend on the availability of various tools. necessary to support operations (Kholil, 2023). It is essential to ensure that enough equipment are available to meet optimal operational needs. Inadequate stock levels may result in disruptions to business operations and miss out on opportunities to make a profit. This leads to unexpected costs (Kholil et al., 2021). On the other hand, over-stocking products can lead to unnecessary storage costs. Therefore, effective inventory planning and control is important to maintain adequate stock levels and Prevent shortages or surpluses to reduce product storage costs To achieve this goal In this study Two methods are used: the Economic Order Quantity (EOQ) method and the Just-in-Time (JIT) method (Lufti et al., 2022). The EOQ method determines the most cost-effective order quantity for raw materials. Considering the minimum cost and scheduling a new order. EOQ calculations, the amount of stock can be reduced. This results in cost savings for improving inventory storage efficiency. And the JIT method is an inventory management approach that focuses on purchasing materials in the required quantity and at the right time to precisely when required for production or operational activities (Mu'mi et al, 2023). JIT calculations are intended to be used to improve time and reduce procurement costs by using inventory control methods. The company can increase the efficiency of inventory management. Improve operational efficiency and reduce costs associated with excessive inventory or stock levels.

- Optimization Model

Inventory optimization is the process of ensuring to right product in the right place, the right time, in the right quantity and appropriate quality to match with customers' needs and procuring products to serve customers. Optimization with Inventory management can be achieved by classifying inventory and demand forecasting models to support inventory management (Dutta et al., 2017). Providing the appropriate level of inventory Model, a company should maintain using guidelines "Traditional" and "Advanced" for anticipating customer needs. It emphasizes the efficiency of inventory management. Many articles focus on

"Optimization model" for "inventory management" (Ropi et al., 2021). Although many discoveries are clear to today's researchers, the search for new and better models to optimize inventory management continues to focus on specific supply chains. Many articles focus models (Becerra et al., 2021) models focus on the interaction of optimization models to determine and stochastic information sharing in the supply chain (Kulkarni et al.,2021). Some models are single stock models (Krzyzaniak, 2022) and others are multi-stock models. (Faramarzi-Oghani, 2022) The use of regression functions for inventory management is common (El Jaouhari, 2022).

Methodology

The methodology with A Meta-Analysis of Eyeglass manufacturing supply chain efficiency for protection global crisis impacted with 2 processes for considering with factory impacted with Eyeglass manufacturing supply chain efficiency as below.

1st Part is Systematic Reviews and Meta-Analysis (PRISMA) by searching the factor from databases published over the past 10 years from 2013 to 2024. The main published from Scopus international database which the search terms used "Inventory Control", "Manufacturing", "Global crisis" and "Lens". Figure 4 shows the PRISMA diagram as below.

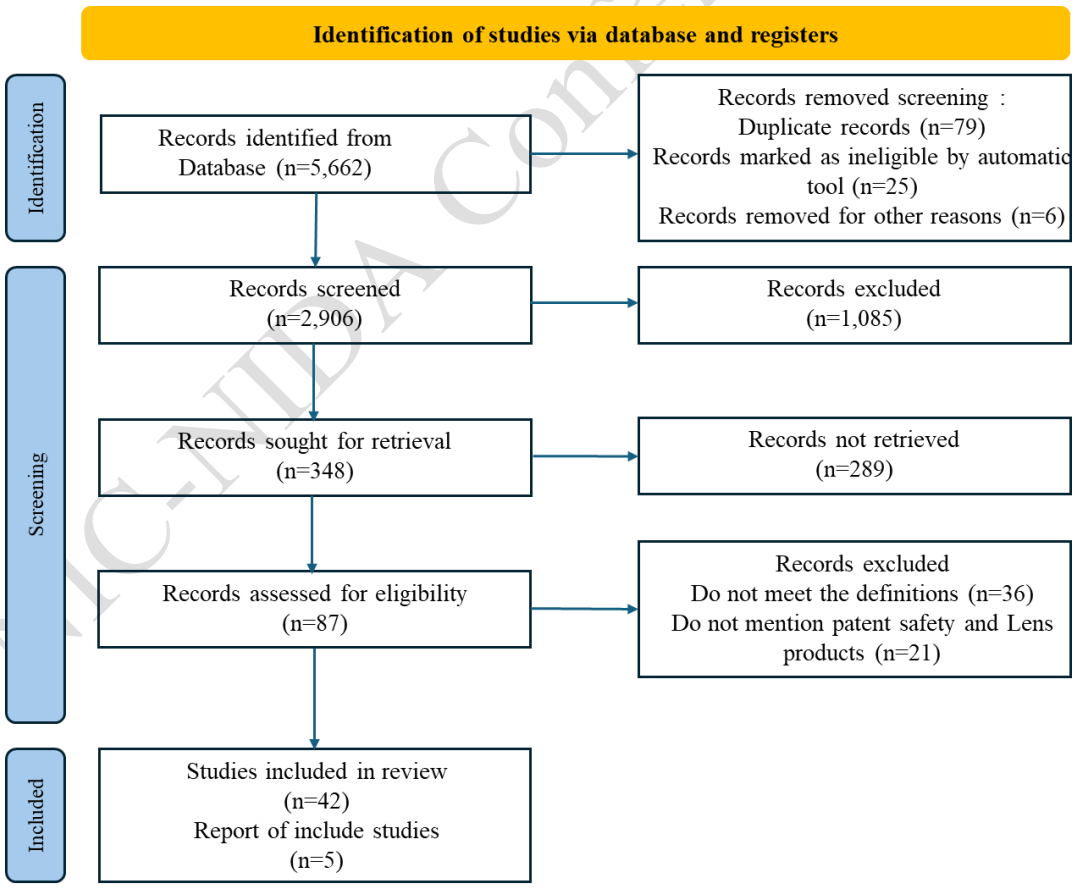

Figure 4: PRISMA diagram for inventory control concern with Eyeglass Lens Business

2nd part is focusing group from professor with eyeglass lens supply chain management as Asia Pacific SCM region, Europe SCM region, America SCM Region, Global Supply & Demand plan, Global Manufacturing and Manager SCM function (Thailand) which number professor focus group 14 persons. This paper used SIMPLE model by brainstorming with SCM Eyeglass Lens Business Expert for selecting the key factor impacted with eyeglass lens manufacturing to impacted with Inventory control.

Result of Research

Exploratory research using the terms “Inventory Control”, “Manufacturing”, “Covid-19” and “Lens” were conducted. A Meta-analysis is using a PRISMA flow operation process (Haddaway et al., 2022). After eliminating duplicates, the screening process with abstract review. The articles were excluded (n = 1,085) if they are not relevant to Inventory control and manufacturing with lens products. The screening process was conducted accordingly with the articles remaining (n = 87). In the full-text review, the articles retained 42 items from articles and 5 items from inventory control papers. For A Meta-analysis, the 13 factors Eyeglass Lens inventory control performances are categorized under an inventory control with the main keys SIMPLE model for Inventory control target in 6 domains as follows: Safety Stock, Information integration, Methodology, Decision, Products Life Cycle and Economic condition. This model can adapt with inventory control target by minimize cost and high service level to customer. The Eyeglass Lens inventory control analysis is displayed by VOS viewer as Figure 5 below.

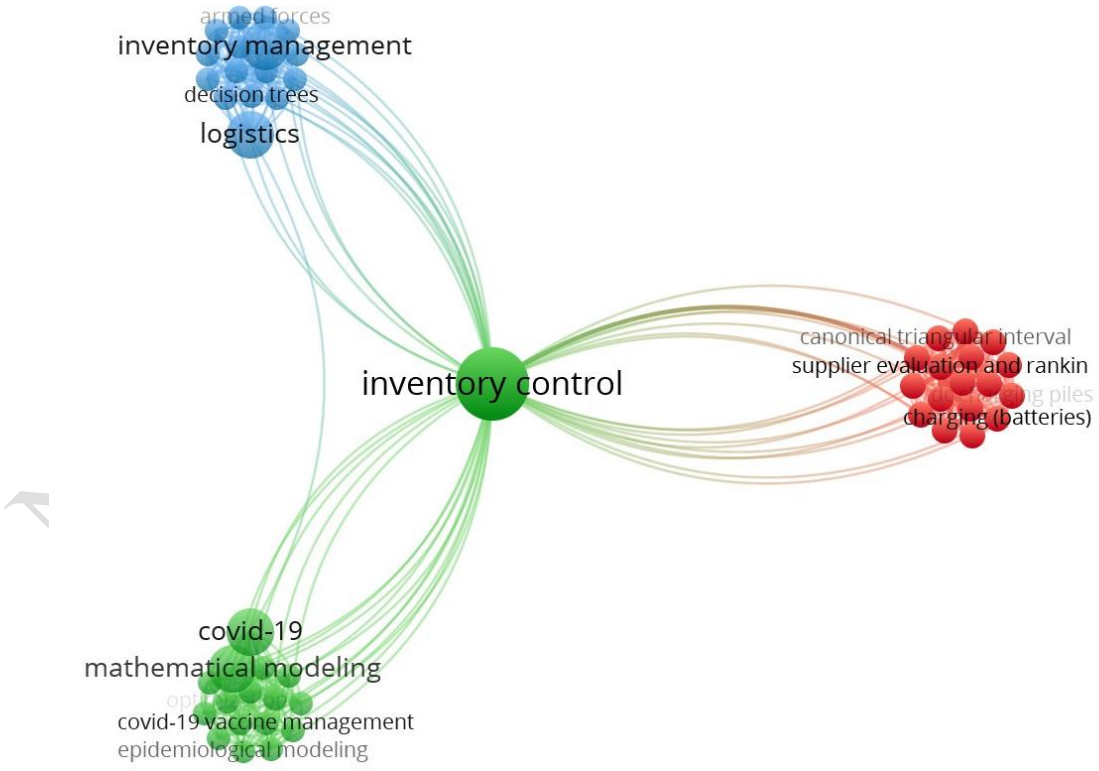

Figure 5: The Eyeglass Lens inventory control Factors in Global crisis by VOS viewer

From the data analysis of Eyeglass Lens inventory control performance, the factors of inventory control related with 20 items as Table 1. A literature review concern with stakeholders in the Eyeglass Lens inventory control process and minimize with inventory cost in Eyeglass Lens manufacturing.

Table 1: The Eyeglass Lens inventory control factors weight in Global crisis.

No.	Keyword	Occurrences	Total link Strength	Ratio
1	Inventory Control	3	49	56%
2	Charinging	1	17	20%
3	Distribution Assesment	1	17	20%
4	Environment Protection	1	17	20%
5	Fuzzy Rule	1	17	20%
6	Logistics Operation	2	17	20%
7	Sensitivity Analysis	1	17	20%
8	Supplies Evaluation and rinking	1	17	20%
9	Demand Forecast	1	16	18%
10	Charecteristic Technology	1	16	18%
11	Decision Tree	1	16	18%
12	Digital Storage	1	16	18%
13	Inventory Management	2	16	18%
14	Machine Leanining	1	16	18%
15	Mathematical Modeling	1	16	18%
16	Operation Planning	1	16	18%
17	Optimization Model	1	16	18%
18	Site Selection	1	16	18%
19	Socio economic condition	1	16	18%
20	Supply Chain Management	1	16	18%

The Key function with Eyeglass Lens inventory control consisted of Suppliers function, Manufacturer function, Distributor Function, and Hospitals/Eyecare providers Function. The main Eyeglass Lens inventory control factor impacted with protect loss supply and achieved demand from consumer in Global crisis period. In this study, the researcher focused on the Inventory Control Factor with Eyeglass lens supply chain domain categorized as SIMPLE. Anyhow Eyeglass Lens caused by delivery performance and match with demand trend. Eyeglass Lens manufacturing must protect the risk eyeglass lens in manufacturing and reduce the risk trigger to impact with Eyeglass Lens business as shown in Table 2.

Table 2: Inventory management Factor with Eyeglass lens domain categorized as SIMPLE.

Domain	Factor	Risk Triggers
Safety Stock	Inventory Management	* Holding inventory Cost * Demand & Supply uncertainty * Product obsolescence Rate * Supplier inventory fulfillment
	Machine Leaning	* No knowledge and experience with machine * Loss efficiency from machine breakdown
	Optimization Inventory	* Operating profit impact * Products disposal from expire and * Rate of products obsolete manufacturing fulfilment
Information integration	Service Level	* Loss customer * A key component with Rate of exchange * Loss information with sale promotions
	Socia economic condition	* System integration effective lack * Extensive networking system
Methodology decision	Evaluation and Ranking	* Service Quality & Responsiveness * wrong partners Selection
	Operation Planning	* Quality Poor * Low production yields * Higher cost and Design changes with products
Products Life Cycle	Distribution assessment	* Variety with Products * A single source of Products * Short life cycle with products tend
	Demand forecast	* Order fulfilment errors * Inaccurate forecasts due to longer lead time * Swing demand and seasonality
Logistic Management	Digital Storage	* Information infrastructure breakdown * Lack of compatibility in IT platforms among SC partners
	Site Selection	* Products allocation * High level Inventory from manufacturing keeping * High Transportation Cost
Economic condition	Logistic Operation	* Port delay due to over port capacity * Congestion with Custom Clearance process * Higher transportation costs from mode selection
	Environment Protection	* Transportation stop and Breakdown * Excessive handing from border crossing and change in transportation mode

Research Findings and Discussion

According to the research result study, the Eyeglass Lens manufacturing supply chain efficiency for protection global crisis impacted as domain 6 items and 13 factors to impact with inventory control performance for protection risk with eyeglass lens business. The function related with Eyeglass Lens manufacturing consist of 4 functions as Supplier function, Manufacturing function, Distribution inventory function and Hospital & Eyecare providers function which it's related the operation process management in global crisis period. The SIMPLE model is key drive operation process with Supply chain management as;

S: Safety stock is concerned with Manufacturing function and Distribution function which it's related with Inventory management, Machine Leaning and Optimization Inventory. The main risk impacted with inventory holding Cost inventory from FG & Raw material from supplier to match with the Demand and supply to customer.

I: Information integration is concern with Hospital & Eyecare providers function and Supplier function which it's related to Service Level and Socia economic condition. The main risk impacted with the communication network Loss customer and information loss in sale promotion period and concern with information network in commercial and marketing function.

M: Methodology decision is concerned with Supplier function and Manufacturing function which it's related to Evaluation and Ranking (Supplier and Customer) and Operation Planning for decision making. The main risk impacted with Quality of service including responsiveness or poor Quality and low yield to more waste and production cost with manufacturing after wrong decision.

P: Products Life Cycle is concerned with Distribution function and Hospital & Eyecare providers function which it's related with Distribution assessment with customer sharing tendency with demand forecast. The main risk impacted with Products variety and Products produced from a single source and short life cycle because Eyeglass lens has expired date. Anyhow the demand swing & seasonality and fulfilment errors will impact with inventory to over demand and dispose due to longer lead time keeping.

L: Logistic Management is concerned with Manufacturing function and Distribution function which it's related with Digital Storage and Site Selection from more location to support global demand. The main risk impacted with Information infrastructure breakdown, Lack of compatibility in IT platforms among SC partners to importance with information in all function with supply chain. Moreover, products allocation to all manufacturing to impacted with Inventory high from kept all manufacturing and high cost of transportation.

E: Economic condition is concerned with Hospital & Eyecare providers function and Supplier function which it's related with Logistic Operation and Environment protection.

This study proposed a model of Eyeglass lens inventory management performance for protection Eyeglass Lens to loss supply with customer demand in Global crisis period. The model can be useful with Eyeglass Lens inventory management to issues upstream and downstream for implementing inventory control strategies to improve overall performance with Eyeglass Lens business in Global crisis period as Figure 6.

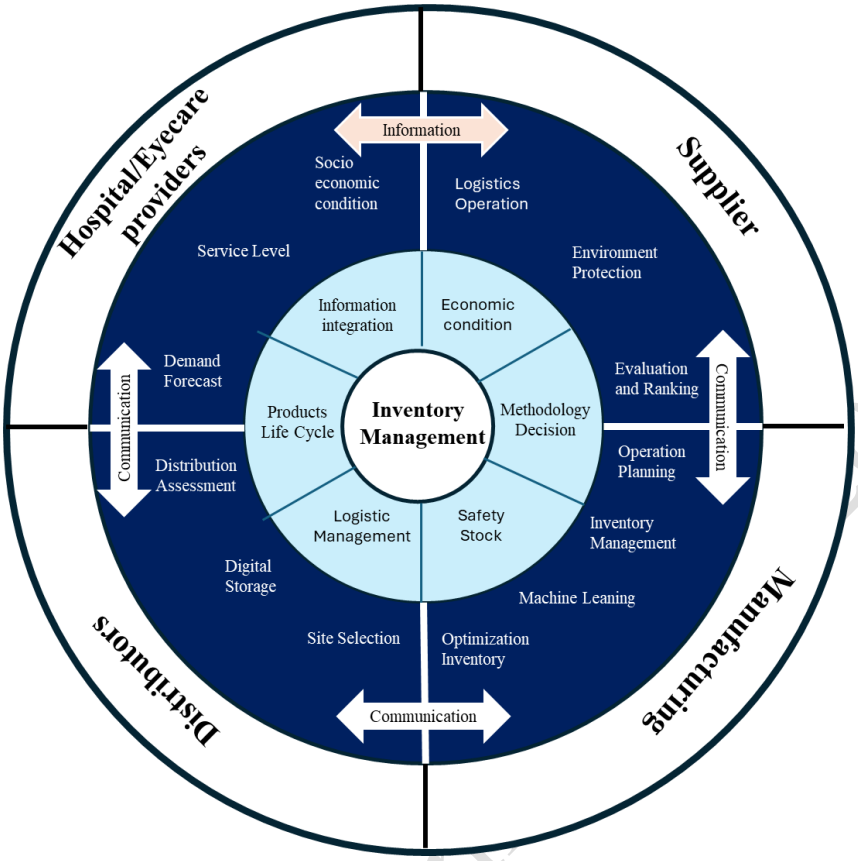

Figure 6: The model of Eyeglass Lens Inventory Management performance in Global crisis.

Conclusion, Limitations, and Recommendations for Future Research

This document is Supply Chain Management, it has a lot of documents and control the inventory control. The current article does not have an eyeglasses business and global crisis in research. However, researchers will need to learn more documents to compile and compile risk data from all affected global crises. In our research need to study inventory control and investigate factors impacted with Eyeglass Lens Supply Chain Management in Global crisis. As first theme, we consider the Eyeglass Lens inventory optimization strategy to manage the inventory cost holding in supply chain management function and close cooperated with S&OP team to support customer demand and improve forecast efficiency. Second, we discussed commercial and marketing with order quarterly and seasonal with consumer demand which consider the inventory with region distribution for making strategy holding cost. Thirdly, Eyeglass Lens inventory control model was discussed using studies in Global crisis period that have previously addressed this topic. The author has studied this information to demonstrate its practical application with Eyeglass lens supply chain management. Fourth, we examine how inventory management goals conflict among stakeholders and influence management decisions. There is often conflict between the three main stakeholders: consumers, regional distribution and production group on the issue of the eyeglass lens business.

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Lean and Green Transportation to Build Sustainability Performance of Transportation Service Provider of Food Cold Chain in Thailand

Tamonwan Fuangprayoon[1] and Natapat Areerakulkan[2]

Abstract

This research addresses key challenges in Thailand's food cold chain transportation sector, focusing on the need for environmental sustainability and operational efficiency. It aims to study green and lean transportation management, service efficiency, and sustainability performance, while developing a structural equation model to validate the relationships between these variables. Enhancing the efficiency of transportation service providers in the cold chain system with green and lean management concepts involves several overlapping aspects, such as waste reduction, which is part of environmental issues, and efficient resource management to improve the overall performance of an organization in terms of environmental, economic, and social aspects, both directly and indirectly. The transportation in the cold chain system is a crucial industry driving Thailand's economy. As the demand for cold chain transportation services increases, it inevitably impacts the environment. Coupled with competitive conditions and the growing trend of environmentally-conscious consumers, it is essential for cold chain logistics service providers to adapt and enhance their services sustainably. This aligns with global and national interests in environmental preservation and sustainable efficiency improvement, as outlined in the National Economic and Social Development Plan. Therefore, this research aims to provide guidelines for enhancing the efficiency of transportation services in cold chain to reduce service costs while improving business performance. Additionally, it seeks to establish a foundation for new long-term business competition. The findings can be used by transportation service providers and related industries to plan and formulate policies for sustainable business performance improvement.

Keywords: Lean Transportation, Green Transportation, Sustainability Performance, Efficiency, Transportation Service Provider, Food Cold Chain

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Introduction

The increased emissions of carbon dioxide and other greenhouse gases (GHGs) into the atmosphere are causing global warming, a major factor driving climate change in all regions of the world. This results in various natural disasters, including more frequent and severe extreme heat events, ocean heatwaves, floods, droughts, an increased frequency and intensity of tropical cyclones, and significant reductions in sea ice, snowpack, and permafrost in the Arctic region. The primary causes of these issues largely stem from energy production, manufacturing, deforestation, transportation, food production, residential energy use, and excessive consumption. Food production activities that involve transportation play a significant role in increasing the emissions of carbon dioxide, methane, and other greenhouse gases. This includes the energy and fuel required for food packaging and distribution, which needs more energy to maintain proper temperature control for food quality compared to the transportation of regular goods. (United Nations Thailand, 2022) Moreover, climate change is a key factor contributing to the global food crisis, which is characterized by rising food prices leading to widespread food shortages that are expected to worsen over time. This affects global food production activities, making it difficult for some populations to access sufficient and nutritious food. The consequences may include increased hunger, malnutrition, social unrest, and geopolitical tensions, impacting governments, organizations, and individuals alike. (U.S. Embassy & Consulates in Italy, 2022) Transportation management thus plays an increasingly important role in the logistics industry, meeting customer demands. Additionally, it helps reduce greenhouse gas emissions, air and noise pollution, as well as traffic congestion. (Almohanna et al., 2020) Another significant obstacle to sustainable logistics business operations is the adherence to traditional operational frameworks that focus solely on economic performance. This results in policies, strategic plans, and organizational action plans that do not align with sustainable development. (Khan, 2015), (Burawat, 2019) This is evidenced by data from the end of 2021, showing that there were 36,733 logistics businesses registered with the Department of Business Development in Thailand. Among these, 4,411 were newly established logistics businesses, an increase of 34.1%, while 891 businesses closed, a decrease of 5.7% compared to the previous year. (Trade policy and strategy office, 2022) Therefore, if logistics service providers genuinely aim for sustainability, relying solely on traditional measures or indicators that focus exclusively on economic performance is insufficient. It is essential to also consider environmental and social performance to ensure that business operations are sustainable in all dimensions. (Saulick, et. al., 2023) It can be seen that strategic planning by business operators is crucial in today's highly competitive environment, driven by changes in various factors such as economic conditions, social dynamics, politics, and technology. Therefore, logistics business operators should prioritize strategic decision-making to reduce costs, meet customer demands, and sustainably enhance competitiveness. (Wiangkam, et. al., 2022) Thus, the transportation of food products within the cold chain system significantly contributes to environmental pollution due to its high energy consumption and substantial emission of carbon gases. This is because operations require low temperatures and use a higher amount of fuel compared to conventional logistics systems. (Leng, et.al., 2024)

Losses and damages from improper transportation methods affect product quality, economic value, and cause issues like waste disposal, health risks, and inefficiencies in the food chain. These problems also increase greenhouse gas emissions, worsening climate change. Addressing these challenges requires improving processes to enhance efficiency and maintain quality and safety across the supply chain. (FMCG Gurus, 2021) Food transportation providers should prioritize environmental sustainability by reducing plastic packaging, using eco-friendly materials, and adopting greener transport vehicles. These measures will improve service efficiency, lower costs, meet consumer demands, and support sustainable food delivery.

Due to customer demand focusing on service efficiency coupled with sustainability, alongside stringent regulations, a highly competitive environment has emerged. The concept of green management and lean principles are therefore being utilized to improve operational efficiency in tandem with social and environmental sustainability. (Rathi, et al., 2022) Combining green management and lean concepts impacts the sustainability efficiency of supply chains in social and environmental dimensions. (Kosasih, W., et al., 2023) Measuring and evaluating performance in food supply chain operations using lean and green management concepts can improve the efficiency of food supply chain management. (Bottani, Bigliardi & Rinaldi, 2022) Sustainable development has become a fundamental requirement for every organization, ensuring sustainability across economic, social, and environmental dimensions. (Rajarajeswari & Anbalagan, 2023) Moreover, Kim, Na & Ha (2024) provide an additional confirmation that the coexistence of carbon neutrality and capitalism can be realized if environmentally friendly management is proven to enhance profitability. The focus of green logistics practices (GLPs) is on maximizing energy efficiency in logistics services, potentially leading to cost reductions for companies.

From the above information, green transportation and lean transportation factors complement each other and are integral to enhancing the efficiency of transportation service providers within the cold chain of the food industry in Thailand. The researcher expects that the results of this study It can be used as a guideline in formulating strategies and policies to develop organizational operations that increase competitiveness and address environmental challenges. Green transportation emphasizes minimizing environmental impacts through the use of low-impact technologies and methods across transportation systems, including vehicle management, transportation, warehousing, and distribution to consumers. Additionally, lean transportation aims to reduce waste and improve efficiency in transportation processes by focusing on eliminating non-value-added activities such as waiting times, movement of goods, and inventory buildup. This approach enhances transportation efficiency and reduces transportation costs. Can be summarized as follows.

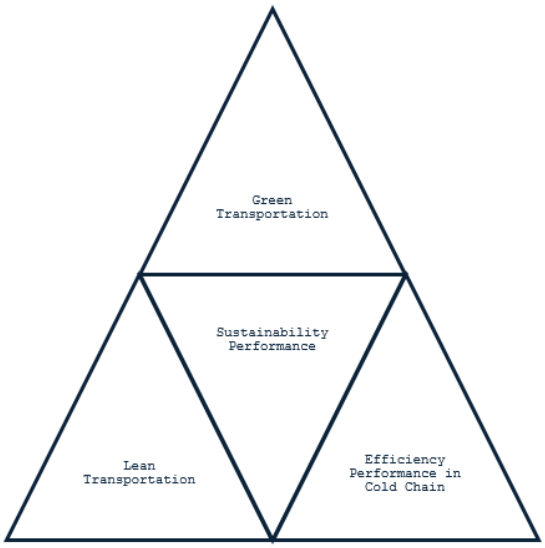

Figure 1: Component of Sustainability Performance for a Transportation Service Provider in the Food Cold Chain in Thailand.

As shown in Figure 1, the concept of Sustainability Performance for a Transportation Service Provider in the Food Cold Chain in Thailand should include the implementation of green transportation, lean transportation, and efficiency performance in the cold chain.

Research methodology

This research is based on a theory elaboration approach is the study of concepts and theories by using the existing descriptive methods and presenting a conceptual framework derived from the synthesis of theoretical variables discovered in the logistic service provider business, with logical and theoretical explanations together with the discovery of empirical data Theoretical elaboration method for supporting the idea. The proposed framework is based on deductive reasoning. To lead development of the model to study the causal relationship between the latent variable, the observed variable, as well as the direct effect and the indirect effect of the Lean Transportation and Green Transportation Influencing Sustainability Performance and efficiency of Transportation Service Provider of Food Cold Chain in Thailand

The conceptual framework development

The conceptual framework developed in this research is based on a combination of the concept of Efficiency and Sustainability Performance of Transportation Service Provider of Food Cold Chain with variables that are driving factors Green Transportation and Lean Transportation which is defined by.

Transportation Service Provider of Food Cold Chain

Food products are perishable and delicate items, requiring meticulous control of temperature, humidity, and environmental conditions. The cold chain system is essential for maintaining quality and minimizing damage during transportation and distribution, especially crucial in domestic transport where land transport is pivotal (Thron, Nagy, & Wassan, 2007). According to Ketzenberg & Ferguson (2003), 15% of perishable goods experience quality loss during these processes. Highlighted by Hosseini Bamakan, Ghasemzadeh Moghaddam, & Dehghan Manshadi (2021), the cold chain serves as a temperature-controlled supply chain critical for public health and safety, managing complex processes to ensure product quality from production to consumer delivery.

Transportation in the cold chain system involves a temperature-controlled transport system aimed at maintaining the quality of goods that require specific temperature and humidity control throughout production, transportation, storage, distribution, and delivery to consumers. Service providers in the food cold chain transport perishable goods under specified temperature and humidity conditions (Bishara, 2006).

Rodrigue & Notteboom (2020) underscore that the effectiveness and reliability of the cold chain system in the food industry depend on several key factors. Firstly, the refrigeration system establishes optimal storage and transportation environments using methods like refrigerated containers and air conditioning, tailored to the nature of the goods. Secondly, temperature-controlled transportation utilizes specialized vehicles to maintain consistent temperature and humidity levels during transit, supported by robust containers adaptable to varying transport conditions and GPS technology for real-time monitoring. Additionally, cold storage facilities maintain controlled temperatures essential for preserving goods before distribution to distant markets. Lastly, efficient processing and distribution practices uphold

product integrity through suitable packaging, processing methods, health compliance, and assembly techniques, minimizing losses during transport.

In summary, transportation service provider of food cold chain ensure the safe transportation of perishable goods, focusing on maintaining quality and safety from production through the entire distribution chain to the end consumer. They rely on advanced transportation tracking systems and cold storage facilities, employing standardized packaging and appropriate packing practices to mitigate losses during transportation.

Green Transportation

Rehman, et al. (2023) proposed that green transportation management policies can reduce the ecological footprint for a sustainable environment, as transportation activities significantly contribute to greenhouse gas emissions. Therefore, an evident environmental solution is to implement green management concepts in the transportation sector to ensure the use of environmentally friendly vehicles and avoid the emission of toxic gases. They developed a green transportation index and an environmental degradation index from the ecological footprint for the top 10 countries undergoing energy changes, covering data from 1990 to 2018, using advanced and complex econometric techniques to analyze the data. The results confirmed that green transportation can reduce environmental degradation from the ecological footprint. Moreover, control variables such as innovation, domestic investment, and quality of governance help preserve environmental quality by reducing the ecological footprint.

Jovanovic, Zolfagharinia, & Peszynski (2020) surveyed the current status of environmental sustainability in the Canadian trucking sector by examining the types of environmentally friendly initiatives adopted by Canadian trucking companies and the drivers and barriers related to their implementation. This cross-sectional survey examined eight small to medium-sized trucking companies operating in Ontario, Canada. The green transportation management concepts adopted by these companies included five aspects: the use of alternative energy, vehicle technology and innovation, operational strategies, vehicle modification, and transportation preparation. The findings revealed that Canadian trucking companies face numerous challenges and barriers when implementing environmentally friendly concepts in their transportation processes, with varying degrees of success in each case. Nonetheless, the different approaches demonstrated a focus on achieving sustainability goals.

Musolino, Rindone, & Vitetta (2019) presented the concept of green transportation management through green transportation and logistics planning in port areas, aiming to integrate green energy production within ports to power electric vehicles for transportation and logistics services. This involves designing the best routes for cargo transport or passenger movement by modeling the development of electric vehicles and optimizing transportation route design.

Accordingly, green transportation management encompasses the use of green energy, advancements in technology and innovation, effective route management, and thorough transportation preparation. This model can be applied by analyzing the efficiency and sustainability performance of transport service providers in the food cold chain. Implementing green transportation can enhance service capabilities, thereby linking to competitive advantages and sustainability.

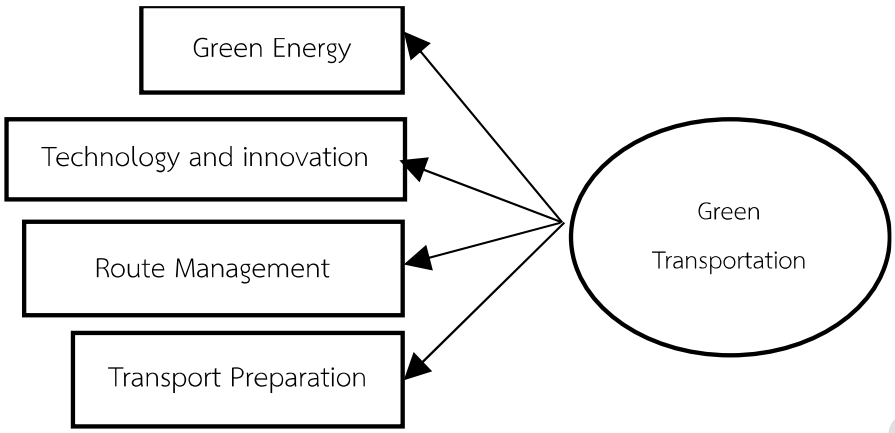

Figure 2: Green Transportation Indicators

As in figure 2, Green Transportation comprised four indicators are Green Energy, Technology and innovation, Route Management and Transport Preparation.

Lean Transportation

Implementing lean concepts in transportation and service operations (Kawa et al., 2019) can significantly enhance operational quality (Kuvvetli & Firuzan, 2019), reduce operational costs, and minimize waiting times (Saravanan et al., 2018). Additionally, it can effectively meet customer demands and improve service efficiency (Nainaar & Masson, 2018; Ponte et al., 2018). Transportation and logistics companies face new challenges and constraints that require attention to financial aspects, methods, and techniques to ensure efficient operations, cost reduction, and elimination of redundancies, which directly impact financial outcomes and service quality. Standardized and well-documented processes are crucial for improving transportation and logistics services, as they align operations and produce better results in less time with reduced waste. Addressing gaps is essential to prevent changes that can lead to significant losses in quality, time, and financial performance (Lobo & Pinho, 2019)

Lobo & Pinho (2019) proposed lean transportation management by improving operations to enhance transportation service efficiency, including delivering close to the first pickup point to reduce transportation distance and empty vehicle costs, utilizing GPS and tracking systems to help drivers avoid traffic congestion and detours, moving vehicles only to the next pickup point after the final delivery, establishing an office in the warehouse to prevent drivers from moving around the warehouse and office for paperwork or contacting warehouse staff, unloading goods at destinations based on size or safety requirements, and confirming all advanced delivery conditions at the delivery site to avoid returns due to incorrect deliveries. Garza-Reyes et al. (2017) suggested optimizing road transport operations through setting primary goals and targets for each activity in the transportation process, using information technology systems to store and collect data for decision-making, improving resources by increasing staff, adopting technology, and enhancing activities using lean concepts, planning and scheduling deliveries to agree with customers and inform recipients in advance, and facilitating clear communication between employees, managers, and customers for smooth process flow. Colicchia, Creazza, & Dallari (2017) discussed continuous transportation through green and lean management to identify potential multimodal transport demands. They examined factors facilitating the shift from road to rail transport, including planning, resource

management, service, collaboration, legal conditions, and incentive plans. Collaboration is also proposed to support transportation mode shifts.

Applying Lean Transportation in the food cold chain enhances operational quality, reduces costs, and minimizes waiting times through standardized processes, efficient methods, and GPS optimization, supporting multimodal transport with effective planning, resource management, and collaboration. In summary, lean transportation consists of process flow, transportation mode integration, transportation planning, and collaboration.

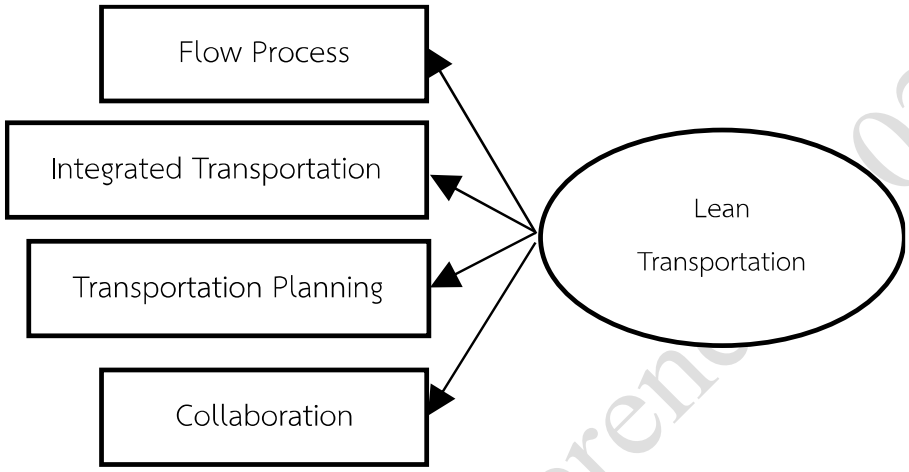

Figure 3: Lean Transportation Indicators

As in figure 3, Lean Transportation comprised four indicators are Flow Process, Integrated Transportation and Transportation Planning and Collaboration.

Efficiency Performance in Cold Chain

Kumar, Tyagi, and Sachdeva (2023) highlight 16 key performance indicators (KPIs) for optimizing cold chain service efficiency, focusing on maintaining product quality and safety amid changing environmental conditions. Key aspects include adequate cold storage facilities, energy-efficient temperature control, and minimizing the use of harmful refrigerants. Real-time temperature monitoring and robust employee training are vital for reducing safety risks and quality loss. The quality of transportation infrastructure and the control of environmental factors like temperature and humidity significantly impact product integrity. Efficient technological solutions and temperature control equipment are crucial for preserving freshness and reducing waste, while effective traceability systems mitigate risks associated with temperature fluctuations, fraud, or contamination. Furthermore, government policies supporting infrastructure development and regulating resource use and emissions are critical for enhancing cold chain efficiency. Improving market infrastructure supports sustainable development, reduces losses, and increases market access. Balancing operational costs with environmental impacts and product quality is essential for achieving economic efficiency.

Additionally, Bardi et al. (2006) presented five factors for measuring transportation service efficiency: Speed, for timely delivery while maintaining product condition; Economy, for minimizing transportation costs and setting low service rates; Safety, for preventing damage

and loss to passengers, goods, and vehicles; Convenience, for ensuring ease of use and well-equipped, ready-to-use vehicles; and Certainty and Punctuality, for delivering goods on time with the capability to track and specify delivery times throughout the transportation route.

In conclusion, key performance indicators for efficiency performance in cold chain focus on product quality, storage, energy-efficient temperature control, and training, while five factors for measuring transportation service efficiency are Speed, Economy, Safety, Convenience, and Punctuality. From these concepts, the components of Efficiency Performance in Cold Chain can be summarized as key elements including Service Level, Reliability, Quality Control, Management, Traceability, and Energy Saving.

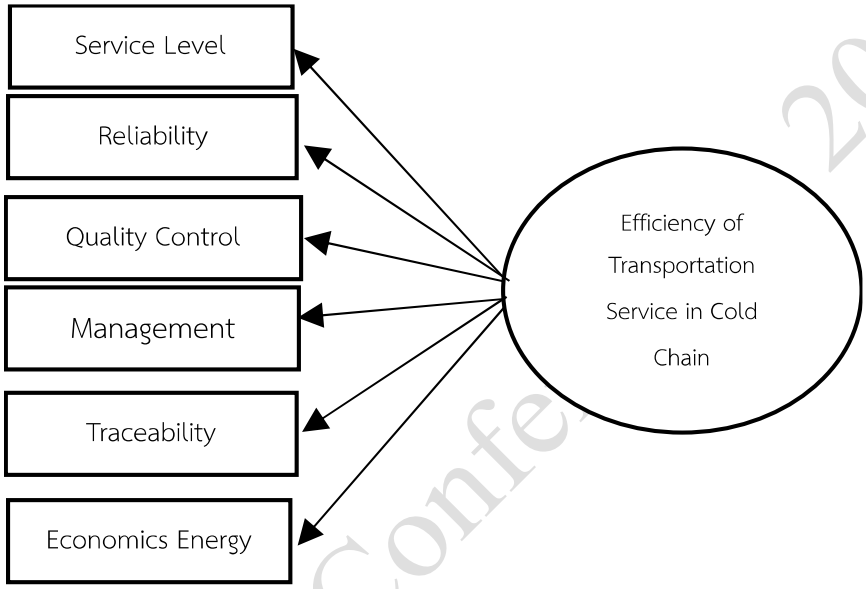

Figure 4: Efficiency of Transportation Service in Cold Chain Indicators

As in figure 4, Efficiency of Transportation Service in Cold Chain comprised six indicators are Service Level, Reliability, Quality Control, Management, Traceability and Economics Energy.

Sustainability Performance

The 17 Sustainable Development Goals (SDGs) encompass three main dimensions: Economic, Social, and Environmental. The environmental goals include six indicators: SDG6 (Clean Water and Sanitation), SDG7 (Affordable and Clean Energy), SDG12 (Responsible Consumption and Production), SDG13 (Climate Action), SDG14 (Life Below Water), and SDG15 (Life on Land) (Kostoska & Kocarev, 2019).

Cetinkaya et al. (2011) presented principles for applying sustainable management in three areas: 1) Social – starting with clearly defined social objectives, business units in the supply chain must prioritize health, safety, and the welfare of employees, partners, and customers, minimizing negative social impacts; 2) Economic – businesses may set goals related to revenue, costs, profits, product and service quality, efficiency, and customer responsiveness; and 3) Environmental – businesses need to reduce the environmental impacts of supply chain

activities, such as minimizing pollution, maximizing resource efficiency, and promoting waste reduction and recycling.

Based on these concepts, the 17 Sustainable Development Goals (SDGs) encompass Economic, Social, and Environmental dimensions, focusing on targets like Clean Water, Affordable Clean Energy, Responsible Consumption, Climate Action, Life Below Water, and Life on Land. Sustainable management principles span Social (health and safety priorities), Economic (revenue, cost, and quality goals), and Environmental (pollution reduction and resource efficiency) dimensions, together defining sustainability performance across these three components.

Summary, Prior research, such as Hosseini Bamakan et al. (2021), highlights the increasing significance of environmentally sustainable practices in logistics. Studies on green transportation have demonstrated that implementing eco-friendly strategies, like reducing carbon emissions and fuel consumption, directly enhances both the operational efficiency and sustainability of logistics services. These findings support the hypothesis that green transportation practices positively affect service efficiency and long-term sustainability. Similarly, lean transportation focuses on minimizing waste and optimizing logistics processes. Research by Rodrigue & Notteboom (2020) and others has shown that applying lean principles in transportation can lower costs, improve time management, and elevate service quality, justifying the hypothesis that lean management positively influences transportation efficiency in cold chain logistics. Furthermore, studies like Bishara (2006) have shown that optimizing logistics operations, especially in temperature-controlled environments like the food cold chain, leads to higher service efficiency. The use of advanced technologies, such as GPS for real-time monitoring, supports the hypothesis that enhanced service efficiency leads to improved sustainability performance. Additionally, research by Ketzenberg & Ferguson (2003) demonstrates that sustainability initiatives, such as reducing spoilage of perishable goods, contribute to better business outcomes and competitiveness, further supporting the link between sustainability practices and improved performance for transportation service providers.

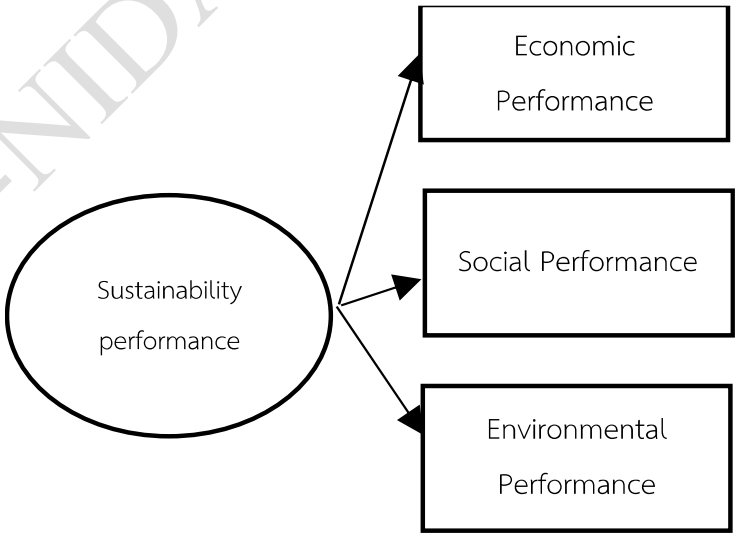

Figure 5: Sustainability performance Indicators

As in figure 5, Sustainability performance comprised three indicators are Economic Performance, Social Performance and Environment Performance.

The relationship between the research variables is integral to understanding how lean and green transportation strategies influence the sustainability performance of food cold chain logistics.

In summary, green transportation management and lean transportation management are hypothesized to positively influence service efficiency, which in turn is expected to improve sustainability performance. The interaction between these variables illustrates how integrated strategies can enhance both operational and environmental outcomes in food cold chain logistics.

Conceptual Framework

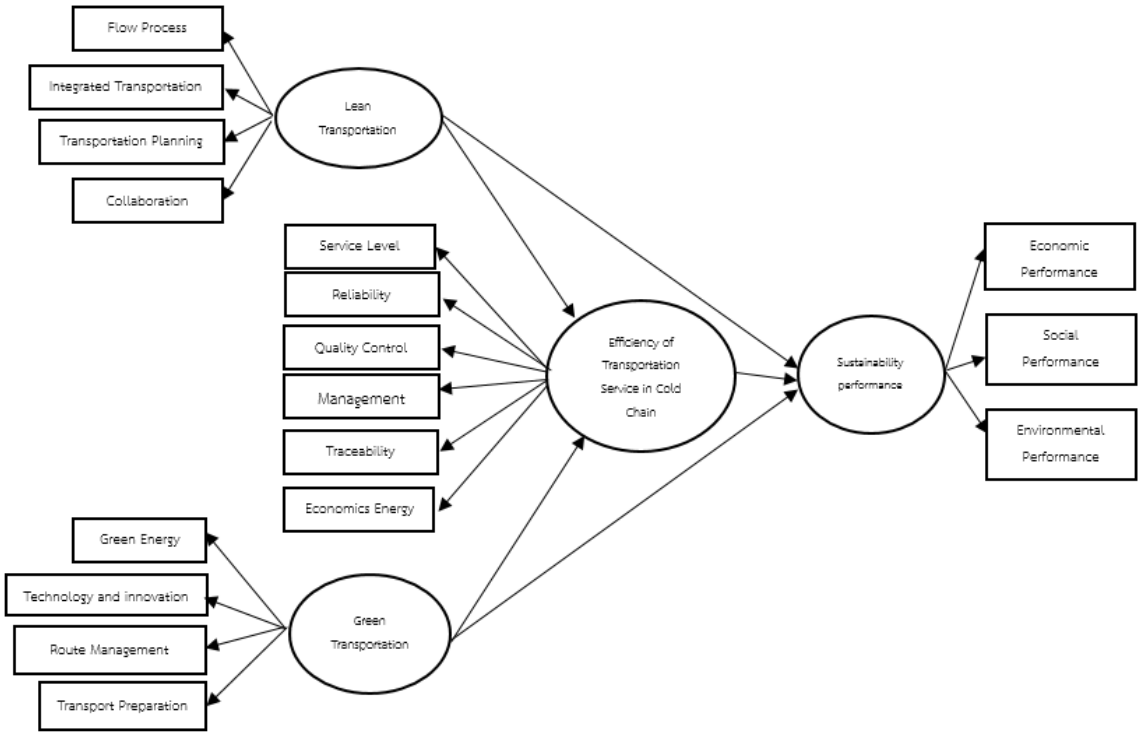

Figure 6: Conceptual Framework

As in figure 6, the research consisted of fourth latent variables: Sustainability performance, Efficiency of Transportation Service in Cold Chain, Lean Transportation and Green Transportation. Sustainability performance comprised three indicators are Economic Performance, Social Performance and Environment Performance. Efficiency of Transportation Service in Cold Chain comprised six indicators are Service Level, Reliability, Quality Control, Management, Traceability and Economics Energy. Lean Transportation comprised four indicators are Flow Process, Integrated Transportation and Transportation Planning and Collaboration. Green Transportation comprised four indicators are Green Energy, Technology and innovation, Route Management and Transport Preparation.

Conclusion

Enhancing the efficiency of food transportation services in the cold chain is critical for operators. It involves developing service processes that adhere to industry standards, providing a framework for improving organizational service efficiency. New operators can use these guidelines for self-assessment and preparation for certification. Service providers must improve processes and delivery capabilities to meet consumer demands and should prioritize environmental preservation by reducing plastic packaging and using eco-friendly transport vehicles to lower costs and meet sustainability goals. Green transportation management focuses on environmental impact reduction, while lean transportation management aims to eliminate non-value-added activities, enhancing efficiency and reducing costs. As demand grows, transportation providers must adapt sustainably to global trends, focusing on structural equation models to improve efficiency, reduce costs, and enhance operations. Therefore, this research aims to provide guidelines for enhancing the efficiency of transportation services in the cold chain, aiming to reduce service costs and improve business performance. Additionally, it seeks to establish a foundation for sustained long-term business competitiveness. The findings can be utilized by transportation service providers and related industries to plan and implement policies for improving sustainable business performance.

Future research

Study logistics activities and performance assessment based on food cold chain transportation activity indicators across economic, social, and environmental dimensions. This will enable cold chain food transportation service providers in Thailand to identify the strengths and weaknesses of their current operations. The findings can be used to develop and improve processes, modify and optimize operations, and allocate resources effectively to meet customer needs while reducing total logistics and supply chain costs.

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The Dynamics of Institutional Logics in Participatory Budgeting: A Com-parative Study Across Thai Local Governments

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Abstract

This study examines the interplay of diverse institutional logics within the framework of Participatory Budgeting (PB) in a Thai local government, emphasizing how these logics impact the effectiveness and democratic nature of PB processes. By employing a case study approach, the research delves into the political, administrative, and citizen empowerment logics, exploring their roles in shaping the implementation and outcomes of PB initiatives. Data were collected through document analysis, semi-structured interviews, and participant observations. The findings reveal a complex interaction of multiple institutional logics, where political interests often over-shadow administrative efficiency and citizen empowerment, undermining the democratic poten-tial of PB. This paper contributes to the literature by highlighting the challenges and dynamics of PB in a non-Western setting, offering insights for policymakers and practitioners on fostering more inclusive and effective governance through PB. Additionally, it calls for a reevaluation of the roles of various institutional logics to enhance the transparency and democratic engagement in PB processes, particularly in similar socio-political contexts.

Keywords: Participatory Budgeting, Institutional Logics, Local Government, Thailand

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