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The effect of optimal temperature management, reliable infrastructure, technology and digitalization, proper packaging, HR competence on cold chain logistics efficiency

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Abstract: The purpose of this literature research is expected to help hypotheses for future authors in determining research related to logistics management. The research article on the effect of optimal temperature management, reliable infrastructure, technology and digitalization, proper packaging, and human resource competence on cold chain logistics efficiency is a scientific literature article within the scope of logistics management. The approach used in this literature review research is descriptive qualitative. Data collection techniques involve literature studies or conducting literature reviews of relevant previous articles. The data used in this research is secondary data, sourced from academic online media such as Thomson Reuters Journals, Sage, Springer, Taylor & Francis, Scopus, Emerald, Elsevier, Web of Science, Sinta Journals, DOAJ, EBSCO, Google Scholar, and digital reference books. In previous studies, one relevant previous article was used to review each independent variable. The results of this literature review article are: 1) Optimal Temperature Management affects Cold Chain Logistics Efficiency; 2) Reliable Infrastructure affects Cold Chain Logistics Efficiency; 3) Technology and Digitalization affect Cold Chain Logistics Efficiency; 4) Proper Packaging affects the Efficiency of Cold Chain Logistics; and 5) HR Competence affects the Efficiency of Cold Chain Logistics.
Keywords: *Cold chain logistics efficiency, HR competence, Optimal temperature management, Proper packaging, reliable infrastructure, Technology and digitalization.*

1. Introduction

In the era of globalization and rapid technological development, the logistics industry is facing increasingly complex challenges, especially in cold chain management. The cold chain is a critical system for maintaining product quality and safety, especially for temperature-sensitive goods such as food, pharmaceuticals, and chemicals. The efficiency of cold chain logistics not only affects the quality of products that reach consumers but also impacts operational costs and customer satisfaction. Therefore, it is important to understand the factors that affect the efficiency of this system.

Cold chain logistics efficiency is one of the most critical aspects of ensuring product quality and safety, especially for perishable goods such as food, pharmaceuticals, and biotechnology products. With globalization and the increasing demand for products that require temperature control, effective cold chain management is becoming a challenge. According to a report by the International Institute of Refrigeration (IIR), approximately 30% of the world's food production is lost due to inadequate cold chain management [1]. This suggests that there is an urgent need to improve the efficiency of cold chain logistics to minimize losses and ensure that products reach consumers in the best possible condition.

One of the key factors affecting cold chain efficiency is optimal temperature management. Improper temperatures during storage and shipping can cause product damage, which in turn can affect a

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company's reputation and customer satisfaction.

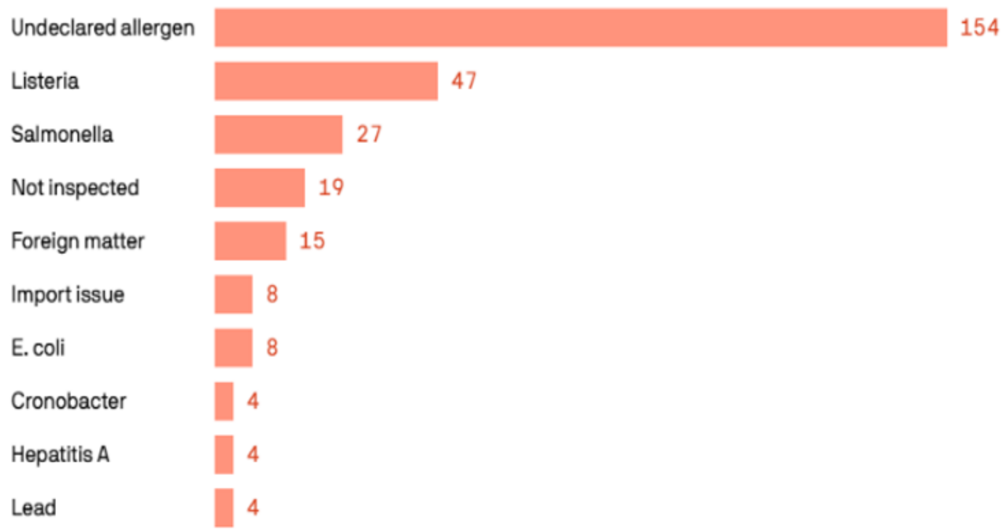

Figure 1.
Food recall data by USDA and FDA in 2023.
Source: axios.com.

Data from the Food and Drug Administration (FDA) shows that more than 50% of food recalls are due to storage temperature violations [2]. Therefore, implementing technology that can monitor and control temperature in real time is critical to maintaining product quality.

Reliable infrastructure also plays an important role in the efficiency of cold chain logistics. Inadequate infrastructure, such as poorly maintained cold storage facilities or inadequate transportation, can lead to dangerous temperature fluctuations. A study by McKinsey & Company found that investments in cold chain infrastructure can improve operational efficiency by up to 20% [3]. Therefore, companies should evaluate and improve their existing infrastructure to support more efficient cold chain operations.

Technology and digitization are also key factors in improving cold chain logistics efficiency. The use of a supply chain management system integrated with Internet of Things (IoT) technology enables real-time monitoring of product conditions, allowing companies to take quick action in the event of temperature deviations. According to a report by Gartner, companies that use digital technology in their supply chain can reduce operating costs by up to 30% [4]. Therefore, investing in technology and digitalization should be a priority for companies looking to improve the efficiency of cold chain logistics.

Finally, human resource (HR) capability is also an important factor that cannot be ignored. Employees who are trained and have a good understanding of the cold chain can identify and address issues that may arise during the storage and distribution process. According to research by the World Economic Forum, companies that have good training programs for their employees can increase productivity by 25% [5]. Therefore, developing HR competencies is a very valuable investment to improve the efficiency of cold chain logistics.

2. Literature Review

2.1. Cold Chain Logistics Efficiency

Cold chain logistics efficiency refers to the ability of a logistics system to manage and distribute products that require specific temperatures to remain in optimal condition. This includes reducing the time and cost of shipping, storing, and handling products. This efficiency is achieved through careful planning, the use of appropriate technology, and effective resource management [6].

The indicators or dimensions contained in Cold Chain Logistics Efficiency are: 1) Delivery Time: Measures the time it takes to deliver a product from origin to destination. Shorter delivery times indicate greater efficiency in the logistics process; 2) Operating Costs: Assesses the total costs incurred in the logistics process, including transportation, warehousing, and labor. Lower costs while maintaining high service quality indicate good efficiency; 3) Product Damage Rate: The percentage of products that are damaged during the delivery process. A low damage rate indicates a well-functioning logistics system [7].

Cold Friendly Logistics Efficiency has been studied by previous researchers conducted by: Yu and Xiao [8]; Konovalenko, et al. [9] and Centobelli, et al. [10].

2.2. Optimal Temperature Management

Optimal temperature management is the process of controlling and monitoring temperatures in the cold chain to ensure that products remain within a safe and effective temperature range. It involves the use of advanced tools and technologies such as temperature sensors, real-time monitoring systems, and management software that can provide accurate data on storage and transport conditions [11].

Indicators or dimensions contained in Optimal Temperature Management, namely: 1) Temperature Compliance: The percentage of time the product temperature remains within the specified range during storage and transportation. A high level of compliance indicates effective temperature management; 2) Temperature Monitoring Frequency: How often the product temperature is monitored during the logistics process. More frequent monitoring can help identify problems earlier and prevent damage; and 3) Response to Temperature Deviations: The time it takes to respond to and correct temperature deviations. A fast response indicates an efficient management system [12].

Optimal Temperature Management has been studied by previous researchers conducted by: Tsang, et al. [13] and Callaway, et al. [14].

2.3. Reliable Infrastructure

Reliable infrastructure in the context of cold chain logistics includes all the facilities and systems needed to support the storage and distribution of products that require controlled temperatures. This includes cold storage facilities, refrigerated vehicles, and efficient transportation systems [15].

Indicators or dimensions contained in Reliable Infrastructure, namely: 1) Refrigeration availability: The number and quality of cold storage facilities available. Adequate infrastructure is essential to maintain product quality; 2) Condition of Transportation Vehicles: Review the condition and capability of refrigerated vehicles used for distribution. Well-maintained vehicles reduce the risk of product damage; and 3) Reliability of transportation routes: Evaluate routes used for delivery, including congestion and other risks. Reliable routes improve delivery efficiency [16].

Reliable Infrastructure has been studied by previous researchers conducted by: Liashenko, et al. [17] and Frankó, et al. [18].

2.4. Technology and Digitalization

Technology and digitalization play an important role in improving the efficiency and effectiveness of the cold chain. Through the use of technologies such as the Internet of Things (IoT), big data, and cloud-based supply chain management systems, companies can monitor and manage the cold chain more effectively [19].

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Indicators or dimensions contained in Technology and Digitalization, namely: 1) Technology Adoption Rate: The percentage of advanced technology used in the logistics process, such as IoT and supply chain management systems. A high adoption rate indicates progress in digitization; 2) Data Accuracy: Measures how accurately data is collected and used to make decisions. Accurate data is critical to improving operational efficiency; and 3) System integration: How well different systems (e.g., inventory management, temperature monitoring) are integrated. Good integration improves supply chain visibility and responsiveness [20].

Technology and Digitalization has been studied by previous researchers conducted by: Gupta, et al. [21].

2.4.1. Proper Packaging

Proper packaging is a critical aspect of cold chain logistics, ensuring that products are protected during storage and transportation. Packaging should be designed to maintain the required temperature, protect the product from physical damage, and minimize the risk of contamination. Good packaging materials, such as thermal insulation and cooling materials, can help maintain product quality [22].

Indicators or dimensions contained in Proper Packaging, namely: 1) Packaging material quality: Evaluate the type and quality of materials used to package products. Good materials can protect products from damage and maintain temperature; 2) Space efficiency: Measures how well packaging uses space during transportation and storage. Efficient packaging can reduce costs and increase capacity; and 3) Leakage or contamination rate: The percentage of product that has leaked or become contaminated due to improper packaging. A low rate indicates effective packaging [23].

Proper Packaging has been studied by previous researchers conducted by: Asim, et al. [24] and Tanksale, et al. [25].

2.4.2. HR Competency

Human resources (HR) expertise in cold chain logistics is critical to ensuring that all processes run smoothly. Employees who are trained and knowledgeable about cold chain management, the latest technology, and food safety procedures can improve operational efficiency [26].

Indicators or dimensions contained in HR Competencies, namely: 1) Employee training rate: Percentage of employees who have received training in cold chain management and the latest technology. Good training improves competency and performance; 2) Employee Satisfaction: Measures employee satisfaction with the work environment and training provided. Satisfied employees tend to be more productive and engaged; and 3) Team performance: Assesses the team's performance in completing tasks and achieving goals. A high-performing team demonstrates high competence in cold chain management.

HR competence has been studied by previous researchers conducted by: Li, et al. [27] and Ližbetinová, et al. [28].

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2.4.3. Previous Research

Table 1.
Previous research.

No	Author (Year)	Research results	Similarities with this research	Difference with this research
1	[29]	-Temperature management variables affect cold chain logistics efficiency -Storage management variables affect cold chain logistics efficiency	The equation with this research is that it discusses the Temperature Management variable as an Independent variable and the Cold Chain Logistics Efficiency variable as the dependent variable.	The difference with this research is in the variable Storage Management, as another dependent variable
2	[30]	IoT infrastructure variables affect the efficiency of cold chain logistics in meat logistics	The equation with this research is that it discusses the Infrastructure variable as an Independent variable and the Cold Chain Logistics Efficiency variable as the dependent variable.	The difference with this research is in the object of research, where previous research focused on the quality of meat carried out by logistics.
3	[31]	-Technology and digitalization variables affect cold chain logistics efficiency -Information variables affect cold chain logistics efficiency	The equation with this research is to discuss the variables of Technology and Digitalization as Independent variables and the Cold Chain Logistics Efficiency variable as the dependent variable.	The difference with this study is in the Information variable, as another independent variable
4	[32]	-Supply chain participation variables affect cold chain logistics efficiency -The right packaging variable affects cold chain logistics efficiency	The equation with this research is that it discusses the Precise Packaging variable as an Independent variable and the Cold Chain Logistics Efficiency variable as the dependent variable.	The difference with this research is in the Supply Chain Participation variable, as another independent variable.
5	[33]	-HR relationship variables affect cold chain logistics efficiency -HR competency variables affect cold chain logistics efficiency	The equation with this research is that it discusses the HR Competency variable as an independent variable and the Cold Chain Logistics Efficiency variable as the dependent variable.	The difference with this research is in the HR Relationship variable, as another independent variable

3. Methodology

This research used a descriptive qualitative approach. This method was chosen because it allows researchers to understand the research concepts related to cold chain logistics efficiency thoroughly, focusing on the context and meaning contained in logistics management. Descriptive qualitative data collection and analysis allows researchers to tailor their approach to the needs of the research and the characteristics of the subject under study, [34].

The data used in this study comes from previous research related to cold chain logistics efficiency. The researcher will analyze the existing literature to identify patterns and trends in logistics management concepts. By using previous research and other references, the researcher can develop stronger, evidence-based arguments and contribute to a broader understanding, [35].

The type of data used in this study is secondary data, which utilizes data from various leading academic journals, including Thomson Reuters Journal, Springer, Taylor & Francis, Scopus, Emerald, Sage, WoS, Sinta Journal, DOAJ, and EBSCO, as well as platforms such as Publish or Perish and Google Scholar. By using these sources, researchers can ensure that the data they collect is valid and accountable. The use of multiple sources also allows researchers to gain a more comprehensive understanding of logistics management from various perspectives, [36].

4. Results and Discussion

4.1. Effect of Optimal Temperature Management on Cold Chain Logistics Efficiency

Based on literature review and previous research that has been done, that Optimal Temperature Management affects Cold Chain Logistics Efficiency.

To improve the efficiency of cold chain logistics through optimal temperature management, what must be done by management are: 1) Temperature Suitability: It must be ensured that each product is stored and transported in accordance with the established temperature standards, so that product quality is maintained; 2) Frequency of Temperature Monitoring: must be carried out periodically using the latest technology to detect changes in temperature in real-time; and 3) Response to Temperature Storage: should be carried out quickly to minimize adverse impacts on the product, such as by using an alarm system or automatic temperature reset.

If the Company's management can implement temperature suitability, frequency of temperature monitoring and response to temperature storage, it will have an impact on the efficiency of cold chain logistics which includes: 1) Delivery Time: can be better controlled because optimal temperature management reduces potential delays due to product damage; 2) Operating Costs: can be reduced by reducing losses due to damaged products or loss of marketability; and 3) Product Damage Rate: will decrease dramatically as products are maintained in ideal conditions during the distribution process.

The results of this study are in line with research conducted by Pajic, et al. [29], which states that there is an influence between optimal temperature management on cold chain logistics management.

4.2. The Effect of Reliable Infrastructure on Cold Chain Logistics Efficiency

Based on literature review and previous research that has been done, that Reliable Infrastructure affects Cold Chain Logistics Efficiency.

To improve the efficiency of cold chain logistics through reliable infrastructure, what must be done by management are: 1) Availability of Coolers: must be ensured to be sufficient at every stage of the supply chain, from storage to distribution, to keep products in optimal condition; 2) Condition of Transport Vehicles: needs to be addressed by performing regular maintenance and ensuring vehicles are equipped with appropriate temperature control technology; and 3) Transportation Route Reliability: should be improved by utilizing mapping technology to select the most efficient path, as well as anticipating potential disruptions such as congestion or poor road conditions.

If the Company's management can implement the availability of coolers, the condition of transport vehicles and the reliability of transportation routes, it will have an impact on the efficiency of cold chain logistics which includes: 1) Delivery Time: can be more predictable because operational disruptions can be minimized, so that products arrive on time; 2) Operational Costs: can be reduced through optimized use of infrastructure and reduced need for repair or replacement of damaged products; and 3) Product Damage Rate: can be minimized because products are kept in ideal temperature conditions throughout the logistics process.

The results of this study are in line with research conducted by Ren, et al. [30], which states that there is an influence between reliable infrastructure on cold chain logistics management.

4.3. The Effect of Technology and Digitalization on Cold Chain Logistics Efficiency

Based on literature review and previous research that has been done, that Technology and Digitalization affect Cold Chain Logistics Efficiency.

To improve the efficiency of cold chain logistics through Technology and Digitalization, what must be done by management, namely: 1) Technology Adoption Rate: should be improved by implementing digital devices and systems, such as smart temperature sensors and IoT devices, to monitor product conditions in real-time; 2) Data Accuracy: should be maintained by utilizing technology that is able to record and analyze data with precision, so that operational decisions can be made based on valid information; and 3) System Integration: should be done by connecting various platforms and technologies across the supply chain, such as warehouse management systems, transport vehicles, and transportation routes, to ensure smooth coordination.

If the Company's management can implement the level of technology adoption, data accuracy and system integration, it will have an impact on the efficiency of cold chain logistics, which includes: 1) Delivery Time: will be more controlled as technology enables more accurate tracking and quick response to potential disruptions; 2) Operating Costs: can be reduced by reducing waste and improving process efficiency, such as resource and energy management; and 3) Product Damage Rate: will decrease as technology-based monitoring ensures products remain in suitable condition throughout the logistics process.

The results of this study are in line with research conducted by Gupta, et al. [31] which states that there is an influence between technology and digitalization on cold chain logistics management.

4.4. Effect of Proper Packaging on Cold Chain Logistics Efficiency

Based on the literature review and previous research that has been done, that Proper Packaging affects Cold Chain Logistics Efficiency.

To improve the efficiency of cold chain logistics through proper packaging, what must be done by the management are: 1) Quality of packaging materials: must be prioritized by using materials that are able to maintain temperature stability and protect products from damage during storage and transportation; 2) Space efficiency: it should be considered by designing packaging that allows optimal use of space in the transport vehicle, so that the number of products that can be transported increases; and 3) Leakage or contamination rate: should be minimized by using reliable sealing technology and ensuring the packaging is resistant to extreme pressure or temperature changes.

If the Company's management can implement packaging material quality, space efficiency and leakage or contamination rate, it will have an impact on the efficiency of cold chain logistics, which includes: 1) Delivery Time: can be more predictable because the product is well protected, so the risk of delays due to damage is reduced; 2) Operating Costs: can be reduced as efficient use of space reduces the need for additional travel, while lower spoilage rates reduce losses; and 3) Product Damage Rate: will be reduced as proper packaging ensures products remain in optimal condition throughout the supply chain.

The results of this study are in line with research conducted by Trivellas, et al. [32] which states that there is an influence between proper packaging on cold chain logistics management.

4.5. The Effect of HR Competencies on Cold Chain Logistics Efficiency

Based on literature review and previous research that has been done, that HR Competence affects Cold Chain Logistics Efficiency.

To improve the efficiency of cold chain logistics through proper packaging, what must be done by management are: 1) Employee training levels: should be improved by providing relevant training, such as temperature management, use of logistics technology, and risk management, so that employees are able to perform their duties more effectively; 2) Employee satisfaction: should be addressed by creating a positive work environment, providing fair compensation, and career development opportunities, so that employees are more motivated to contribute optimally; and 3) Team performance: should be strengthened by building good collaboration among team members, encouraging effective communication, and ensuring solid coordination throughout the logistics process.

If the Company's management can implement the level of employee training, employee satisfaction and team performance, it will have an impact on the efficiency of cold chain logistics which includes: 1) Delivery Time: can be better maintained because trained and motivated employees will work faster and more precisely; 2) Operating Costs: can be reduced by reducing operational errors and increasing team productivity; and 3) Product Damage Rate: will decrease because employees have the knowledge and skills to maintain product quality during the logistics process.

The results of this study are in line with research conducted by Astuty, et al. [33] which states that there is an influence between HR competencies on cold chain logistics management.

5. Conceptual Framework

The conceptual framework is determined based on the formulation of the problem, research objectives and previous studies that are relevant to the discussion of this literature research:

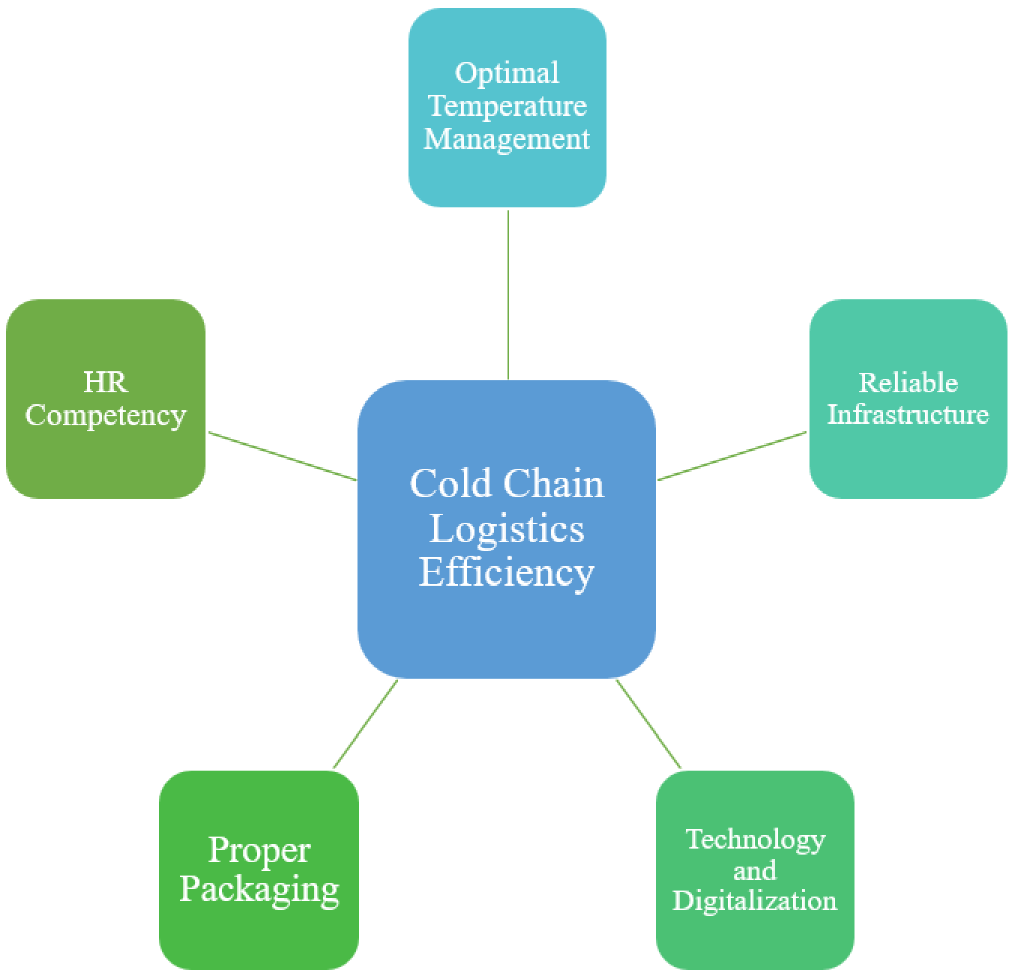

Figure 2.
Conceptual framework.

Based on Figure 2 above, optimal temperature management, reliable infrastructure, technology and digitalization, proper packaging and HR competencies affect Cold Chain Logistics Efficiency. However, in addition to the variables of optimal temperature management, reliable infrastructure, technology and digitalization, proper packaging and HR competence that affect cold chain logistics efficiency, there are other variables that influence, among others:

1) Planning: [13, 37, 38].
2) Resource Availability: [39-41].

3) System Integration: [42-44].

6. Conclusion and Recommendation

Based on the problem formulation, results and discussion above, the conclusions of this study are:
1. Optimal Temperature Management affects Cold Chain Logistics Efficiency;
2. Reliable Infrastructure affects the Efficiency of Cold Chain Logistics;
3. Technology and Digitalization affect Cold Chain Logistics Efficiency;
4. Proper Packaging affects Cold Chain Logistics Efficiency;
5. Human Resource Competency affects Cold Chain Logistics Efficiency.

Based on the above conclusions, suggestions are needed to implement factors that affect the efficiency of cold chain logistics.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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