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# SUSTAINABLE COLD SUPPLY CHAIN MANAGEMENT OF TUNA AGRO-INDUSTRY: A SYSTEMATIC LITERATURE REVIEW AND FUTURE RESEARCH

**RB Tri Joko Wibowo[1*], Marimin[2], Machfud[2], Elisa Anggraeni[2], Taryono[3]**
[1]Doctoral Program in Agricultural Industrial Engineering, Graduate School of IPB University
Postgraduate Building Wing Rectorate 1st-4th Floor Dramaga Campus, Indonesia 16680
[2]Department of Agricultural Industrial Technology, Faculty of Agricultural Technology, IPB University
Lingkar Akademik Street Dramaga Campus, Bogor, West Java, Indonesia 16680
[3]Department of Fisheries Resource Management, Faculty of Fisheries and Marine Sciences, IPB University
Agatis Street Dramaga Campus, Bogor, West Java, Indonesia 16680

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*Correspondence: rb.trijwibowo@apps.ipb.ac.id, rb.bowo@gmail.com

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**Abstract**

The tuna agro-industrial cold supply chain faces complex challenges. The implementation of cold chains has economic, social, and environmental implications. Breaking the cold chain directly reduces tuna quality. To overcome these challenges, an effective and efficient cold chain management method that focuses on the aspects of risk, performance, value chain, and sustainability is required. This study aimed to analyze the methods used in cold chain management and develop an integrated framework to increase the effectiveness and efficiency of sustainable cold supply chain management in tuna agro-industries. This study uses a systematic literature review (SLR) approach. Scientific article search databases using Scopus, Google Scholar, and others in 2013-2023. The selection resulted in 86 articles for further studies. The results of this study show that there are still very few cold chain studies in the tuna agro-industry. Cold chain studies on risk, performance, and sustainability aspects are dominated by quantitative methods with the following percentages: 76%, 58%, and 92%, respectively. By contrast, studies on the value chain aspect are dominated by descriptive qualitative methods (89%). This study found that the tuna cold chain problem in Indonesia is a soft problem on the upstream side and a hard problem on the downstream side. These two properties are rarely considered in single cold chain studies. The properties of the soft and hard systems were studied using qualitative and quantitative methods, respectively. In future research, we will develop an integrated framework for tuna agro-industry cold chain management in terms of performance, risk, value chain, and sustainability by considering the soft and hard aspects of the cold chain from onboard the ship to the consumer.

Keywords: agro-industry, cold chain, performance, risk, sustainability, tuna

## Manajemen Rantai Pasok Dingin Berkelanjutan pada Agroindustri Tuna: Tinjauan Literatur Sistematis dan Penelitian Masa Depan

**Abstrak**

Rantai pasok dingin agroindustri tuna menghadapi tantangan yang kompleks. Penerapan rantai dingin memiliki dampak ekonomi, sosial, dan lingkungan. Putusnya rantai dingin berdampak langsung pada penurunan kualitas tuna. Untuk mengatasi tantangan tersebut, diperlukan metode manajemen rantai dingin yang efektif dan efisien dengan memperhatikan aspek risiko, kinerja, rantai nilai, dan keberlanjutan. Kajian ini bertujuan untuk menganalisis metode yang digunakan dalam pengelolaan rantai dingin dan mengembangkan kerangka terpadu yang digunakan untuk meningkatkan efektivitas dan efisiensi manajemen rantai pasok dingin yang berkelanjutan pada agroindustri tuna. Kajian ini menggunakan

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pendekatan *systematic literature review* (SLR). Pangkalan data pencarian artikel ilmiah menggunakan Scopus, Google Scholar, dan yang lainnya pada rentang tahun 2013-2023. Hasil seleksi mendapatkan 86 artikel terpilih untuk dikaji lebih lanjut. Hasil kajian menunjukkan bahwa kajian rantai dingin pada agroindustri tuna masih sangat sedikit. Kajian rantai dingin pada aspek risiko, kinerja dan keberlanjutan didominasi oleh metode kuantitatif dengan persentase sebagai berikut: 76%, 58%, dan 92%. Sebaliknya, kajian pada aspek rantai nilai didominasi oleh metode kualitatif deskriptif (89%). Kajian menemukan bahwa permasalahan rantai dingin tuna di Indonesia bersifat soft problem di sisi hulu dan hard problem di sisi hilir. Kedua sifat tersebut jarang yang dipertimbangkan dalam satu penelitian rantai dingin. Sifat *soft system* dikaji dengan metode kualitatif dan sifat *hard system* dikaji dengan metode kuantitatif. Untuk penelitian ke depan, penelitian ini mengembangkan kerangka terpadu pengelolaan rantai dingin agroindustri tuna pada aspek kinerja, risiko, rantai nilai, dan keberlanjutan dengan mempertimbangkan aspek *soft* dan *hard system* rantai dingin sejak di atas kapal hingga ke konsumen.

Kata kunci: agroindustri, keberlanjutan, kinerja, rantai dingin, risiko, tuna

## INTRODUCTION

Tuna is one of the products of fisheries. Indonesian tuna fisheries are divided into two categories: industrial and traditional methods (Firdaus, 2019). The fishing sector in Indonesia makes up about 2.73% of the country's GDP, with a value of 555.04 trillion in 2023 (BPS, 2023). Indonesia is the largest tuna producer in the world with production of around 19.1% of the world's total tuna supply. The export value of Indonesian tuna in 2023 will be USD 927.2 million or 16.47% of the total value of Indonesian fishery exports (PDSPKP, 2024).

The Indonesian fisheries and marine sector faces several challenges. Challenges with distance and quality are directly associated with the cold chain (Perbowo, 2021). The challenges faced in cold chain management vary according to the characteristics of the perishable product (Mercier *et al*., 2017). The tuna agro-industry is one of the parties in the tuna cold supply chain. The stakeholders in the tuna cold supply chain are fishermen, collectors, fish processing units, and exporters (Jati *et al*., 2014; Supriatna *et al*, 2014; Mustaruddin *et al*., 2016; Sukiyono *et al*., 2018). Fish processing units are agro-industries that process tuna into derivative products such as tuna steak (Abdullah *et al*., 2011; Utari *et al*., 2023), dried salted tuna (Pattipeilohy *et al*., 2023), loin and dried block tuna (Leiwakabessy & Wenno, 2019).

The tuna cold chain needs to be studied because cold chain management is an essential tool in maintaining the quality and safety of fish, as well as its economic value (SEAFDEC, 2019), especially in maintaining the quality of tuna. The term "cold chain" describes a process where temperature control is applied to every step of the process (Nguyen *et al*., 2022) on-time deliveries, and satisfied customer requirements, while preventing products from going to waste, which is especially important in the context of a developing country. This study aims to evaluate and select the best cold chain logistics service providers (CLPs) regarding their sustainability performance. For this evaluation, a multi-criteria decision making (MCDM). The three fundamental standards of the cold chain are traceability, security, and quality (Lailossa, 2015) safety and traceability**.** The cold chain is also a major part of the food value chain (UNEP & FAO, 2022) and can prevent losses that generally occur along the fish value chain for various causes (HLPE, 2014). There are three types of losses: quality losses, market force losses, and physical losses (Ward, 1997). The cold chain prevents losses more in terms of quality losses than in terms of physical losses.

Food loss, as defined by the FAO, is when food suppliers along the supply chain—apart from retailers, food service providers, and consumers—make decisions and take actions that result in a decrease in the amount or quality of food (Irianto & Giyatmi, 2021). Because fisheries are perishable and the cold chain is not implemented as well as it should, there is a 40 percent loss overall (Arista *et al*., 2022). Reducing commodity losses is one strategy to close the gap between fish supply and production (Ward, 1997). As part of the stakeholders who implement the cold chain, tuna agro-industry and fishermen play an important role in controlling food loss.

Food loss is the result of ineffective cold chain implementation (Singh *et al.*, 2018b). Less food loss and waste would lead to more efficient land use and better water resource management with positive impacts on climate change and livelihoods (FAO, 2017). However, the implementation of the cold chain affects human health and the environment (Dagsuyu *et al.*, 2021)which affects human health and quality of life, is applied for temperature-sensitive and perishable products. Any problems occurring in the cold chain can cause deterioration in products, causing poisoning, death, or various diseases. There are many stages in the cold chain itself and the risk significance level of each stage is different. Therefore, the risks that occur depending on the weight of the stages in the cold chain should be defined and minimized and action plans are needed to be formed. Every action in the action plan cannot be implemented simultaneously since each action requires a different amount of budget and time resources of the companies are finite. Hence, the risks occurring in the cold chain should be minimized with the maximum use of limited company resources. In this study, an integrated mathematical model with analytical hierarchy method and failure mode and effect analysis is proposed that will maximize the weighted risk reduction amount by considering the budget and time constraints of the companies at the same time. The proposed approach has been applied in the 3PL service provider and the results are discussed. According to the results of the study where maximum benefit is aimed with the actions taken against the dangers, the maximum objective function value was obtained at the second and third levels of the workforce and budget values by evaluating the different situations with scenario analyses. In this solution, it is foreseen that by taking 5 actions, improvement will be made in 14 hazards (Dagsuyu *et al.*, 2021). Therefore, the cold chain must be managed sustainably. The nine main components of sustainable supply chain management are stakeholder management, pressures and incentives/drivers and barriers, multi-tier supplier management, supplier selection and evaluation, supplier development, communication and collaboration, risk management, performance management, and sustainable products (Seuring *et al.*, 2022). To achieve goals and overcome obstacles/barriers to sustainable cold chains and at the same time anticipate the impact of cold chains on the environment most effectively and efficiently, a systems approach is needed (UNEP & FAO, 2022).

The cold chain needs to be designed and implemented properly to prevent losses (Pusporini & Dahdah, 2020). The effectiveness and efficiency of supply chain management itself can be seen in three things: performance, risk, and added value (Putri *et al.*, 2020). A sustainable cold chain needs to be evaluated for performance (Aman *et al.*, 2023), risk (Giannakis & Papadopoulos, 2016), value chain (de Moura & Saroli, 2021), and food loss (Lipinski *et al.,* 2013) to determine its effectiveness and efficiency. Therefore, it is necessary to study the effectiveness and efficiency of a sustainable cold supply chain system in overcoming food loss in tuna commodities.

In the context of the tuna cold chain in Indonesia, the study found that the tuna cold chain problem is a complex problem, with both soft systems on the upstream side and hard systems on the downstream side. This situation is also experienced by other tuna-producing countries, but the problem of the tuna cold chain in Indonesia is more challenging because Indonesia is an archipelagic country. The tuna agro-industry needs to anticipate this complex cold chain problem situation because it is very risky for the continuity of the company's business. If these risks are not anticipated, the agro-industry's performance targets will be hampered. The performance of the agro-industry itself is in line with the value chain of tuna commodities. The highest value of tuna is when it is fresh and will experience a rapid decline (food loss) if not handled properly. Therefore, agro-industry requires appropriate risk, performance, value chain, and sustainability management methods.

The value of tuna is largely determined by supply chain management and value chain management (Supriatna *et al.*, 2014; Jati *et al.*, 2014). There is still little literature studying the tuna agro-industry, especially on the topic of cold chain handling and sustainability issues regarding cold chain implementation. Several systematic literature review studies have examined the cold chain, including by Ashok *et al.* (2017), Gurrala & Hariga, (2022), Kruijssen *et al.* (2020), Shashi *et al.* (2018), and Vrat *et al.* (2018). However, a systematic literature review that examines the cold chain in tuna agro-industry has not been found. By conducting a systematic literature review, research developments in the field of cold chains in general, in the field of tuna fisheries, and on sustainability issues will be known. The application of the cold chain to other commodities and other countries can be adapted to be applied to the tuna cold chain in Indonesia. In this way, it is hoped that appropriate approaches and methods can be identified for implementing the cold chain in the tuna agro-industry in a sustainable manner.

This study uses a systematic literature review approach to determine the methods and approaches used in looking at the effectiveness and efficiency of sustainable cold supply chain systems in 4 research questions (RQ): RQ 1: what are the methods for risk analysis of the cold chain system?; RQ 2: what are the methods for analyzing the value chain produced in the cold chain system?; RQ 3: What are the methods for performance management analysis in the cold supply chain system? and RQ 4: what are methods for sustainability analysis in the cold supply chain system?. The next step is to develop a framework for integrating aspects of risk, performance, value chain, and cold chain sustainability. An integrated approach is an approach used to integrate risk, performance, value chain, and sustainability. In this study, the integrated approach used is soft system dynamic methodology. By using a soft system dynamic approach, it is hoped that it will produce the actual root causes of complex problems and carry out dynamic simulations to determine the effects of corrective actions on the root of the problem (Rodriguez-Ulloa & Paucar-Caceres, 2005).

The contribution of this study is identifying and analyzing risks, food loss, and sustainability performance of the tuna agro-industry cold supply chain system. It is hoped that this study will become the basis for designing a sustainable cold chain system that contributes to maintaining the quality of perishable commodities (especially tuna) from potential food loss. Lower food loss will have economic, social, and environmental impacts (Sharma & Pai 2015), especially for the tuna agro-industry and fishermen as the main stakeholders. Lower food loss will improve the performance of saving the use of agro-industry resources and will increase fishermen's income because the catch is purchased at a high price. Food loss will suppress excessive tuna fishing efforts to compensate for losses after catching (Magalhães *et al.*, 2022).

## MATERIALS AND METHODS

This research uses the PRISMA methodology in conducting SLR (Swartz, 2011). The research flow following the PRISMA methodology is illustrated in Figure 1. Document retrieval databases include Scopus, Google Scholar, and other relevant sources. When searching the Scopus database, criteria for the subject areas taken were added, namely environmental science, engineering, decision sciences, and business, management, and accounting. Keywords for search namely "tuna fishing ground", "sustainable cold chain transportation distribution", "tuna fish cold chain", "smart cold chain distribution transportation", "fish quality losses", "tuna value chain", "design cold supply chain", "tuna supply chain" and "sustainable cold chain". Articles published in various journals, including Q1, Q2, Q3, Q4, Sinta 1, and Sinta 2, spanning the years 2013-2023. Some of the approaches applied include selecting, grouping, classifying, and summarizing all articles. The general description is presented in the form of a matrix showing the relationship between the various variables involved, consisting of the author, the year the article was published, and the type of method used. Furthermore, the results of the analysis become the basis for obtaining research gaps or recommendations for future research.

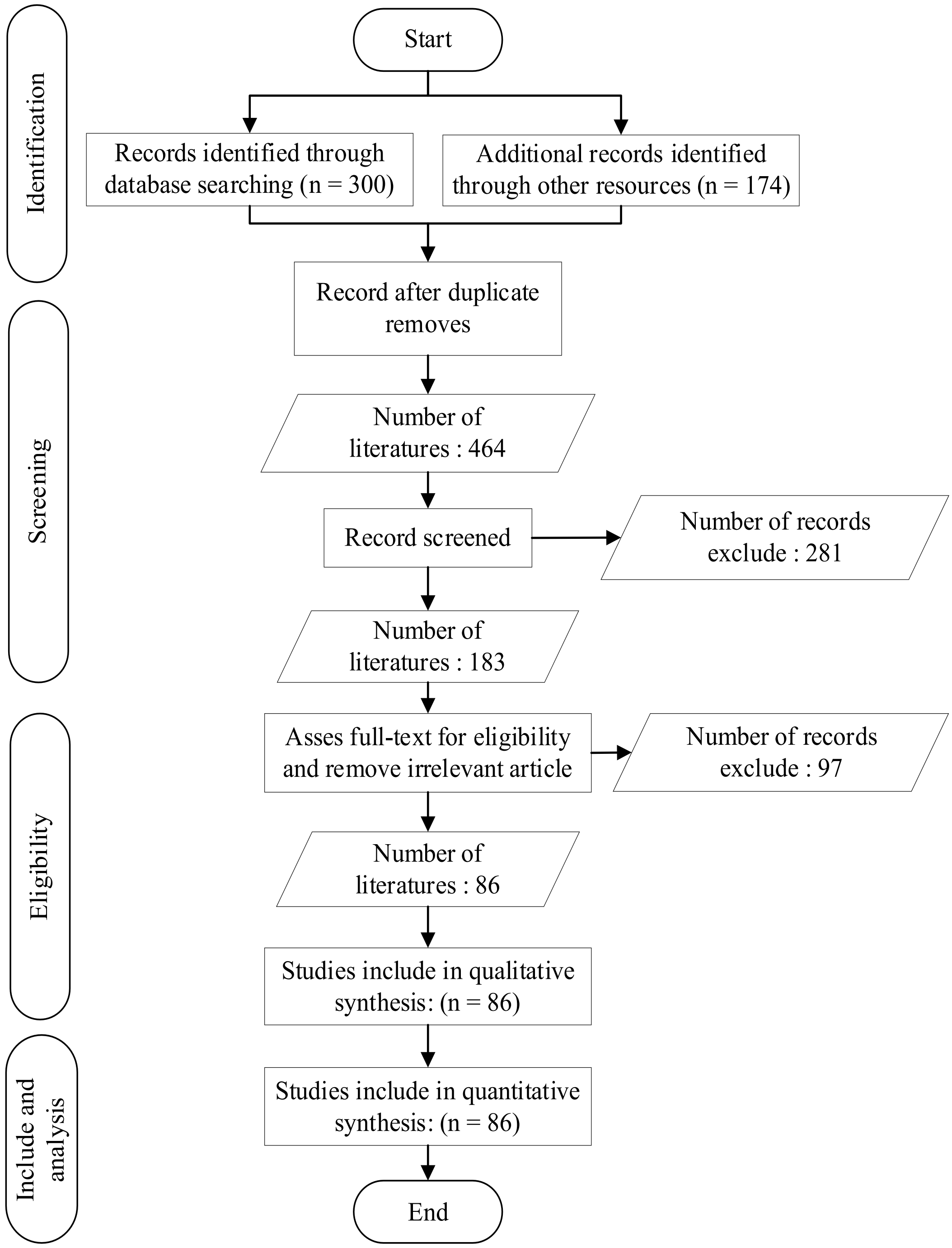


Figure 1 Stages of PRISMA systematic literature review
Gambar 1 Tahapan tinjauan literature sistematis dengan PRISMA

## RESULT AND DISCUSSION

### Evaluation of The Reviewed Articles

The document information was accessed from the Scopus database of 545 documents consisting of 300 research articles, 157 conference papers, 32 conference reviews, 28 book chapters, 28 reviews, 1 short survey, and 1 note. Apart from that, documents were obtained from other sources, such as Google Scholar, totaling 174 articles. After checking, 464 papers were obtained. Next, these papers are evaluated using exclude criteria to filter papers that are in line with the study objectives. The exclude criteria are eliminating the tuna population, the development of the

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oceanographic situation, biodiversity, climate change, ecological engineering, ecological enhancement, habitat creation, ocean sprawl, sea level rise, seawall, fishing ground and related fishing ground, fish aggregating device (FAD), cold chain technical. After carrying out the process of selecting, grouping, classifying, and summarizing all the articles, 86 articles were obtained which were analyzed further. The 86 articles are articles whose documents were successfully downloaded. These articles are grouped into several problem topics, namely cold chain risks, sustainable cold chains, cold chain performance management systems, value chains, and tuna supply chains in Indonesia.

The research also groups tuna supply chain articles in the context of research in the Indonesian region. From Table 1, it can be summarized that 10 papers are qualitative (47%), 11 papers are quantitative (52%) and 1 paper is a mixture of qualitative and quantitative (4,7%). Qualitative methods are descriptive, gap analysis, control chart, laboratory evaluation, and SSM. Quantitative methods are SEM, statistics, FIS, ANP, AHP, SCOR, and system dynamics.

## Cold Chain Risk Method Analysis

The risk that is very likely to occur after fishing is the occurrence of post-harvest losses, especially in traditional fisheries. The causes of post-harvest losses are insufficient ice, too long in port, poor processing techniques and poor equipment (Gyan *et al.*, 2020), the uncertainty of the weather, and the lack of cold storage (Maulu *et al.*, 2020). Food loss can be decreased by improving the cold chain system's functionality and efficiency (Gurrala & Hariga, 2022). The cold chain system's structure is more intricate than it would be in the absence of a cold chain. It is crucial to evaluate risk inside the cold chain logistics network (Zheng *et al.*, 2021) Risks must be identified, managed, and impacted at every point of the cold chain (Dagsuyu *et al.*, 2021; Parenreng *et al.*, 2016; Shen & Liao, 2022). Distribution and transportation pose the greatest risks in comparison to other stages (Zheng *et al.*, 2021). Zhang *et al.* (2020) developed a cold chain risk assessment to manage transportation risks. Wang & Yue (2017) created a pre-warning system to keep the food supply chain sustainable. And foresee the appearance of hazards to food safety.

Risks that arise during transportation are the level of congestion (Chen & Shen, 2022), histamine (Indrotristanto *et al.*, 2022), increased tuna temperature, and the number of bacteria (Suryaningrum *et al.*, 2017). Risks that arise during storage are temperatures above 4 °C, human health risks, food waste, and energy consumption (Duret *et al.*, 2019; Theofania *et al.*, 2020).

Implementing a cold chain requires a large investment so many companies use third-party services. Risks that arise when using third-party services include compliance, container ship schedules and temperature (Yang & Lin, 2017), waste and sustainability (economic, social, environmental) (Khan & Ali, 2021; Nguyen *et al.*, 2022), temperature, economic losses, waste, $CO_2$ emissions from vehicles (Hien & Thanh, 2022), innovation and effectiveness of cold chain processes, applications for track and trace, quality control and inspection (Singh *et al.*, 2018a). The use of cold chains by suppliers is influenced by production costs, quantity losses, transportation costs, price sensitivity, and product freshness levels (Yan *et al.*, 2022).

Several studies have made cold chain risks the subject of study, as shown in Table 2. Each study has differences both in terms of the scope of the cold chain phase and the risks identified. Based on the model type categories by Brandenburg *et al.* (2014), cold chain risk models were grouped as in Figure 2 from several methods in Table 2. In cold chain risk management, many use descriptive and hybrid (analytical & heuristic) models (Figure 2). Studies examining the risk of tuna were only 25% and used descriptive methods.

## Cold Chain Performance Management Method Analysis

The effectiveness of the cold chain does slow down the rate of commodity spoilage but will not increase its nutritional content (Singh *et al.*, 2018a) but on the other hand, if the commodity is damaged it will cause health problems (Duret *et al.*, 2019). Implementing a

Table 1 Tuna research methods and topics in Indonesia
Tabel 1 Metode dan topik penelitian tuna di Indonesia

| Authors | Year | Method | Stakeholder | Topics |
|---|---|---|---|---|
| Jati *et al.* | 2014 | Descriptive | fisherman, collecting, processing unit, government | Level of integration of domestic and foreign markets |
| Lailossa | 2015 | Descriptive | all supply chain stakeholders | Integrated cold chain management system. |
| Parenreng *et al.* | 2016 | Descriptive | fisheries, traders, processors, business owners, government officials, and exporters | Seafood supply chain risk mitigation model |
| Firdaus | 2019 | Descriptive | fisherman, ship owners | Situational description of tuna (price, ship, catch) |
| Indrotristanto *et al.* | 2022 | Descriptive | fisheries, traders, processors, business owners, government officials and exporters | Risks and strategies to anticipate export rejection |
| Supriatna *et al.* | 2014 | SEM | fisherman, processing unit, retail, collecting, exporter, | Fisheries value chain |
| Sukiyono *et al.* | 2018 | Statistics | Producers, consumers, government | Characteristics of tuna prices in Indonesia |
| Resnia *et al.* | 2015 | Gap analysis | processing unit/manufacture | Evaluation of export quality standard |
| Guritno *et al.* | 2021 | FIS | fisherman, fish auction, trader, wholesaler, retailer | Quality determination (product) |
| Lailossa *et al.* | 2016 | FIS | processing unit/manufacture | Quality determination (product and process) |
| Nurani*et al.* | 2016 | Control chart | fisherman | Process of handling tuna from the ship to the fishing port |
| Wardono | 2016 | DEA | fisherman, ship owners | Analysis of resource efficiency levels. |
| Suryaningrum *et al.* | 2017 | Laboratory evaluation | small-scale fishermen | Quality of fresh tuna loin for sashimi prepared on boats by small-scale fishermen |
| Nurani *et al.* | 2018 | SSM | government, ship owners | Designing a management model on resources and fishing technology aspects of Indonesian tuna fisheries |

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Table 1 (continued)
Tabel 1 (lanjutan)

| Authors | Year | Method | Stakeholder | Topics |
|---|---|---|---|---|
| Gigentika *et al.* | 2017 | SSM | government, ship owners, fisherman | Qualitative model of tuna problems |
| Batubara*et al.* | 2017 | SSM, SCOR, MDS | Processing unit, fisherman | Performance of supply chain and sustainability |
| Hartati & Islamiati | 2019 | AHP | government | Fish Collection Center (SLIN) |
| Natasha *et al.* | 2019 | AHP | government | Cold fish supply chain performance management system |
| Pusporini & Dahdah | 2020 | AHP | government, main industries, support industries | The main components of the cold chain |
| Pranoto *et al.* | 2016 | Simulation, ANP | forwarder | Cargo handling policy |
| Nesti *et al.* | 2022 | Sistem dynamics | government, fisherman | Variable relationship model influencing cold storage |
| Rahmantya *et al.* | 2022 | Sistem dynamics | fisheries, processors, business owners, government officials | Dynamic model of fishing vessels |

Table 2 Methods for managing cold chain risks
Tabel 2 Metode untuk mengelola risiko rantai dingin

| Authors | Year | Commodity | Method | Category |
|---|---|---|---|---|
| *Parenreng et al.* | 2016 | Tuna | Descriptive | Descriptive |
| Suryaningrum *et al.* | 2017 | Tuna | Laboratory | Descriptive |
| Gyan *et al.* | 2020 | Fish | IFLAM & QLAM | Descriptive |
| Maulu*et al.* | 2020 | Fish | Descriptive | Descriptive |
| Indrotristanto *et al.* | 2022 | Tuna | Descriptive | Descriptive |
| Yang & Lin | 2017 | Tuna | AHP | Analytical |
| Duret *et al.* | 2019 | Ham | AHP, electree III | Analytical |
| Dagsuyu *et al.* | 2021 | Perishable | AHP, FMEA, MIP | Analytical |
| Nguyen *et al.* | 2022 | Perishable | G-COPRAS, G-AHP | Analytical |
| J. Wang & Yue | 2017 | Dairy | Association rule mining | Heuristic |
| Zhang *et al.* | 2020 | Strawberry | Support vector machine | Heuristic |
| Singh *et al.* | 2018[b] | Pharmaceutical | Fuzzy AHP, Topsis | Hybrid |
| Raut *et al.* | 2019 | Fruit, vegetables | Fuzzy AHP, fuzzy dematel | Hybrid |
| Khan & Ali | 2021 | Perishable | Fuzzy VIKOR, ISM | Hybrid |
| Hien & Thanh | 2022 | Vaccines | Fuzzy, AHP | Hybrid |
| Shen & Liao | 2022 | Food | Expert system, AHP | Hybrid |
| Chen & Shen | 2022 | Perishable | KNN, GA algorithm, AHP | Hybrid |
| Theofania *et al.* | 2020 | Tuna | Test parameters of cold chain | Mathematical programming |
| Yan *et al.* | 2022 | Fruit | Mathematical modeling | Mathematical programming |
| Zheng *et al.* | 2021 | Perishable | Bayesian network | Simulation |

good cold chain will ensure that the quality of the fish is maintained (Watanabe *et al*., 2020).

Cold chain management must be integrated with various stakeholders (Lailossa, 2015). Handling export cargo at the airport is a critical point because there is the potential for the cold chain to be broken (Pranoto *et al*., 2016). Nattassha *et al*. (2019) developed a performance measurement tool for the national fish logistics system. Al-Refaie *et al*. (2020) compiled an ISM model of factors that influence the lean, green, resilient, and agile cold supply chain.

The measures of the effectiveness of cold chain management are food quality and food safety (Calanche *et al*., 2013; Sharma & Pai, 2015), cost, product quality & safety, and service level (Masudin *et al*., 2021).

Meanwhile, the drivers of cold chain management are handling capability, traceability, electronics, and information technology, transaction costs, government policy, standardization, communication quality, infrastructure, temperature monitoring systems (Sharma & Pai, 2015) and the optimal number of fish catches according

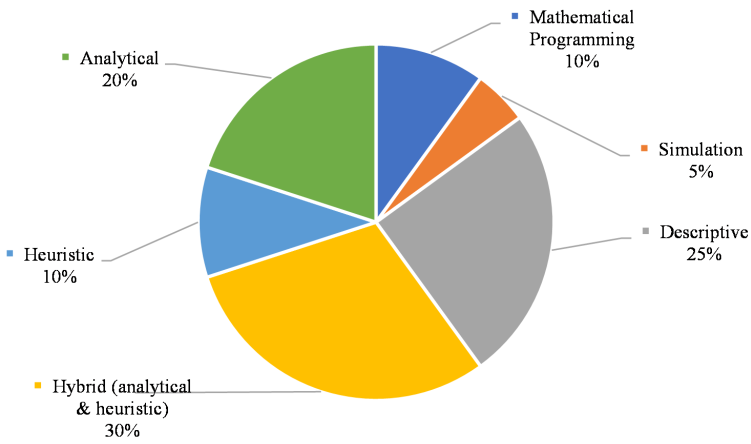


Figure 2 Cold chain risk analysis model
Gambar 2 Model analisis risiko rantai dingin

to the cold storage capacity (Nesti *et al.*, 2022). Meanwhile, the barriers to cold chain management are insufficient professional skills, lack of quality and safety control measures, high number of intermediaries, poor infrastructure, lack of information systems, high installation and operation costs, inadequate education at the farm level, lack of standardization, and lack of government support (Gligor *et al.*, 2018).

Pusporini & Dahdah (2020) stated that there are 3 main factors for the success of the cold chain, namely the role of the government, fish processing units, and fish processing units supporting industries. Isaacs (2013) stated that problems with small-scale fishermen are due to inappropriate policy implementation.

Several studies have made cold chain performance management the subject of study, as shown in Table 3. Based on the model type categories by Brandenburg *et al.* (2014), cold chain performance models were grouped as in Figure 3 from several methods in Table 3. In cold chain performance management, many use descriptive and analytical models (Figure 3).

## Value Chain Methode Analysis

The cold chain is a series of value-added activities that occur under temperature control. The cold chain system is a combination of main and supporting activities (Wang & Yip,

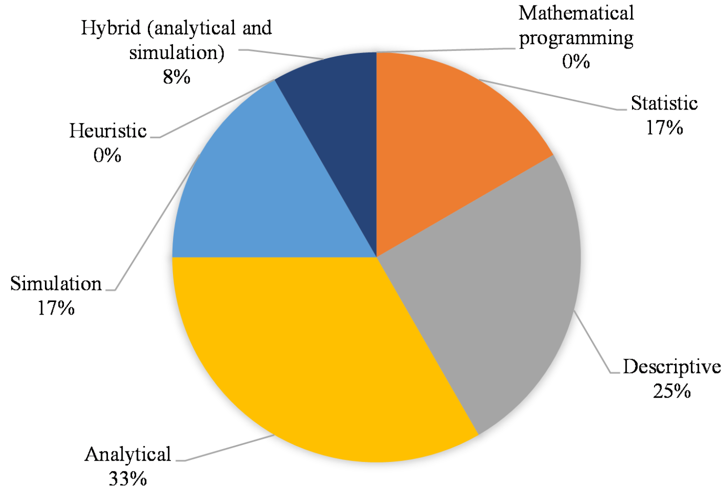


Figure 3 Cold chain performance analysis model
Gambar 3 Model analisis kinerja rantai dingin

Table 3 Methods for managing cold chain performance
Tabel 3 Metode untuk mengelola kinerja rantai dingin

| Authors | Year | Commodity | Method | Category |
|---|---|---|---|---|
| Isaacs | 2013 | Fish | Descriptive key driver | Descriptive |
| Calanche *et al.* | 2013 | Salmon | Data mining, principal component analysis | Statistic |
| Lailossa | 2015 | Tuna | Descriptive | Descriptive |
| Sharma & Pai | 2015 | Perishable | Bayesian network | Simulation |
| Pranoto *et al.* | 2016 | Tuna | Simulation, ANP, BOCR | Hybrid (analytical and simulation) |
| Gligor *et al.* | 2018 | Perishable | Descriptive | Descriptive |
| Nattassha *et al.* | 2019 | Fish | AHP | Analytical |
| Watanabe *et al.* | 2020 | Tuna | Factor analysis | Statistic |
| Al-Refaie *et al.* | 2020 | Vaccines | ISM | Analytical |
| Pusporini & Dahdah | 2020 | Fish | AHP | Analytical |
| Masudin *et al.* | 2021 | Food | SEM-PLS | Statistic |
| Nesti *et al.* | 2022 | Fish | Sistem dynamics | Simulation |

2018). The value chain is the creation of added value starting from raw material production and moving along the linkages with other actors in the cold chain (Rosales *et al*., 2017).

The value chain can be analyzed using a structure, conduct, and performance approach (Thi Nguyen & Jolly, 2018). Key drivers for value chain management are mapping value chains, product segments, how producers access final markets, governance relationships, linkages and trust, upgrading in value chains and costs and margins, and distributional (MP4, 2018).

Value chain management requires synergy between actors, especially in determining prices (Supriatna *et al*., 2014). As actors in the value chain, fishermen get a small portion of the margin and exporters get the largest portion of the margin (Digal *et al*., 2017), even though fishermen face the biggest challenges (Duggan & Kochen, 2016; Rosales *et al*., 2017). Traceability challenges among fishermen require appropriate social interventions rather than technological interventions (Doddema *et al*., 2020). Utilization of technology in traceability systems requires appropriate assessment to suit needs (Óskarsdóttir & Oddsson, 2019). Verdouw *et al.* (2015) designed a cold chain monitoring framework that is integrated with ERP.

Cold chain activities need to be mapped along the value chain. Factors to measure cold chain performance, namely cost, quality and safety, traceability, service level, return on assets, innovativeness, and relationship (Arista *et al*., 2022; Wang & Yip, 2018).

Several studies have made the value chain in the cold chain the subject of study, as shown in Table 4. Based on the model type categories by Brandenburg *et al.* (2014), cold chain value chain models were grouped as in Figure 4 from several methods in Table 4. In the value chain, many use descriptive (Figure 4).

## Sustainable Cold Chain Methode Analysis

Regarding sustainability, components of cold chain costs include carbon emissions (Purnomo *et al*., 2022; Babagolzadeh *et al*., 2020; Hariga *et al*., 2017; Saif & Elhedhli, 2016; Li & Zhou, 2021) and waste (Fasihi *et al*., 2021). Costs, emissions, product quality, and energy often occur in trade-offs (Fan *et al*., 2021; Hu *et al*., 2019).

http://dx.doi.org/10.17844/jphpi.v27i9.54575

Table 4 Methods for managing value chain
Tabel 4 Metode untuk mengelola rantai nilai pada rantai dingin

| Authors | Year | Commodity | Method | Category |
|---|---|---|---|---|
| Supriatna *et al.* | 2014 | Tuna | Statistic (SEM) | Statistic |
| *Verdouw et al.* | 2015 | Floriculture | Framework monitoring | Descriptive |
| Duggan & Kochen | 2016 | Tuna | Descriptive | Descriptive |
| Rosales *et al.* | 2017 | Tuna | Value chain analysis | Descriptive |
| Digal *et al.* | 2017 | Tuna | Descriptive | Descriptive |
| Thi Nguyen & Jolly | 2018 | Tuna | SCP analysis | Descriptive |
| Óskarsdóttir & Oddsson | 2019 | Perishable | Decision tree) | Descriptive |
| Doddema *et al.* | 2020 | Tuna | Descriptive | Descriptive |
| Arista *et al.* | 2022 | Fish | In-depth interview | Descriptive |

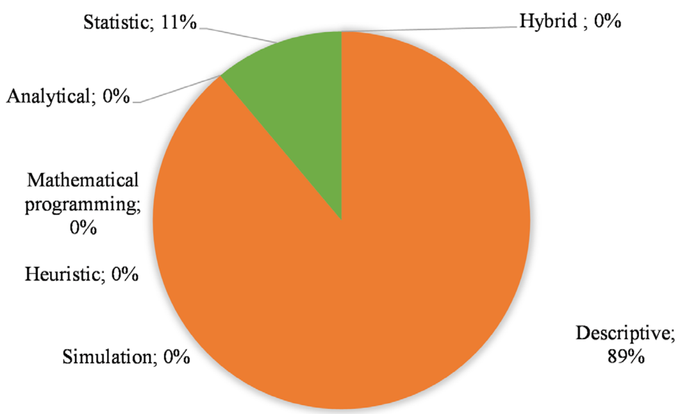


Figure 4 Value chain analysis model
Gambar 4 Model analisis rantai nilai

Temperature can be monitored using sensors (Göransson *et al.*, 2018; Lorite *et al.* ,2017). Temperature conditions need to be shared by relevant stakeholders (Hsiao & Huang, 2016). Temperature data can be used to predict temperature so that energy needs can be adjusted (Hoang *et al.*, 2021) and quality degradation can be anticipated (Lorite *et al.*, 2017; Jiang *et al.*, 2023). Lagarda-leyva (2021) created a dynamic simulation model of fish product packaging along with creating a monitoring dashboard.

Several studies have made sustainable considerations in cold chain management the subject of study, as shown in Table 5. A sustainable cold chain is the key to achieving human well-being, economic growth, and socio-economic development (UNEP & FAO, 2022). Based on the model type categories by Brandenburg *et al.* (2014), sustainable cold chain models were grouped as in Figure 5 from several methods in Table 5. In sustainable cold chain models, many use heuristic and mathematical programming models (Figure 5).

## Research Gap

Management of the tuna agro-industry cold supply chain faces very complex challenges. This complexity is demonstrated by the very diverse types, problems, and research methods used. An overview of research trends

Table 5 Methods for managing cold chain sustainability
Tabel 5 Metode untuk mengelolaa keberlanjutan rantai dingin

| Authors | Year | Commodity | Method | Category |
|---|---|---|---|---|
| Trebar *et al.* | 2013 | Fish | Experiment (RFID) | Experiment |
| Soemardjito & Perdana | 2015 | Fish | LP, least cost allocation | Mathematical programming |
| Saif & Elhedhli | 2016 | Meat, vaccines | MILP, branch-and-bound algorithm | Hybrid (mathematical programming and heuristic) |
| Hsiao & Huang | 2016 | Food | Descriptive | Descriptive |
| Lorite *et al.* | 2017 | Food | Experiment (temperature) | Experiment |
| Hariga *et al.* | 2017 | Food | Iterative search algorithm | Heuristic |
| Singh *et al.* | 2018a | Perishable | MILP | Mathematical programming |
| Göransson *et al.* | 2018 | Food | Sensor monitoring | Experiment |
| Zanoni *et al.* | 2019 | Food | Pemodelan matematika | Mathematical programming |
| Hu *et al.* | 2019 | Meat, milk, aquatic products | System dynamics | Simulation |
| Hartati & Islamiati | 2019 | Fish | AHP, center of gravity (COG) | Analytical |
| Al Theeb *et al.* | 2020 | milk, meat | Integer programming | Mathematical programming |
| Qiu *et al.* | 2020 | Fruit, seafood | multi-objective evolutionary algorithms | Heuristic |
| Babagolzadeh *et al.* | 2020 | Perishable | Iterated Local Search (ILS), MIP | Hybrid (mathematical programming and heuristic) |
| Fasihi *et al.* | 2021 | Fish | LP-Metric | Mathematical programming |
| Mosallanezhad *et al.* | 2021 | Seafood | GA, Simulated Annealing | Heuristic |
| X. Li & Zhou | 2021 | Food | Multi-objective MILP problem, NSGA II | Hybrid (mathematical programming and heuristic) |
| Fan *et al.* | 2021 | Banana | Agent-based modeling | Simulation |
| Golestani *et al.* | 2021 | Perishable | MILP, Epsilon-Constraint Method | Mathematical programming |
| Hoang *et al.* | 2021 | Food | deep learning models | Heuristic |

Table 5 (continued)
Tabel 5 (lanjutan)

| Authors | Year | Commodity | Method | Category |
|---|---|---|---|---|
| Lagarda-leyva | 2021 | Food | System dynamics, | Simulation |
| He & Yin | 2021 | Food | neural network | Heuristic |
| Purnomo *et al.* | 2022 | Fish | MILP, GA | Hybrid (mathematical programming and heuristic) |
| Chen & Shen | 2022 | Fresh product | k-nearest neighbor algorithm, AHP, GA | Hybrid (analytical and heuristic) |
| D. Li & Li | 2023 | Food | multi-objective algorithm | Heuristic |
| Jiang *et al.* | 2023 | Food | K-Means++, LSTM | Heuristic |

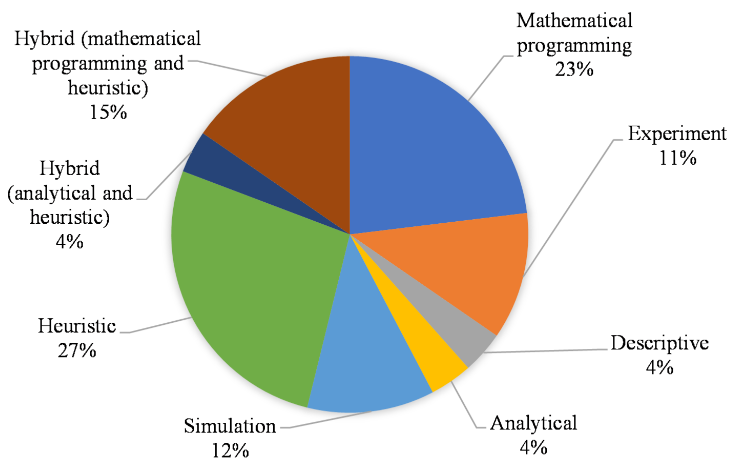


Figure 5 Sustainable cold chain analysis model
Gambar 5 Model analisis keberlanjutan rantai dingin

regarding the cold chain is shown in Figure 6. Figure 6 is the result of analysis of papers obtained from the search process in the Scopus database.

Cold chain topics that are still developing according to Figure 6 are risk, performance, value chain, and sustainability in the tuna agro-industry. Next, we will present several research gaps resulting from the cold chain paper analysis related to the use of methods to solve cold chain problems in the tuna agro-industry from the aspects of risk, performance, value chain, and sustainability. Theory-based empirical research on fish cold chains, especially tuna, is still quite limited and does not cover all aspects. The issue of the tuna agro-industry cold chain is a complex issue with a high level of uncertainty both on the upstream and downstream sides. So far there has been relatively little discussion of the cold supply chain for fish, especially tuna.

In the context of the cold chain in Indonesia, cold chain management is still not integrated from upstream to downstream. It is known from the results of a literature review with research locations outside Indonesia that cold chain research begins with transportation and distribution or warehousing, on the other hand, research literature (especially tuna agro-industry) located in Indonesia is more in the cold handling phase on board ships (especially handline type ships).

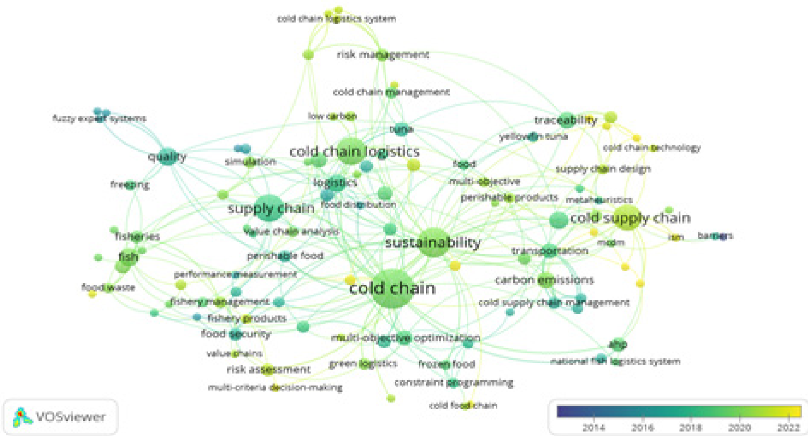


Figure 6 An overview of research trends using VOS Viewer
Gambar 6 Tinjauan tren penelitian menggunakan VOS Viewer

In general, the cold chain literature examines transportation distribution issues more. This is in line with Chaudhuri's conclusion. Chaudhuri *et al*. (2018) concluded that most research in the cold chain field (especially fruit and vegetables) focuses on the distribution stage, besides that, there is limited literature on cold chain studies with fish and meat commodities. In the context of tuna, the cold chain issue after the handling process at the processing unit is relatively controlled due to the use of cooling technology while the cold chain before processing unit is relatively difficult to control, especially when handling on board. Thus, the tuna cold chain from upstream to downstream has problems in both soft and hard dimensions.

In general, research articles in the field of risk examine the operational risks of cold chains in the off-farm transportation phase. One of the risks of cold chain management is food losses. Cold chain and food loss cannot be separated (Chen & Shen, 2022; Li & Li, 2023). Based on the literature analysis, there is still very little research on cold chains in Indonesia which is associated with food loss. In fact, according to Wibowo *et al*. (2014), there is no definite data regarding losses in the fisheries sector in Indonesia. The results of the study found that descriptive and hybrid (analytical & heuristic) methods are most widely used to assess cold chain risks.

The results of the review show that the literature looks at the cold chain stages from their perspectives, making it difficult to compare cold chain performance as a whole. Many studies examine cold chain performance using descriptive and analytical models. Cold chain performance is more a measure of economic performance. Several studies have examined the tuna value chain. However, most research studies the tuna value chain with a descriptive approach and they all boil down to financial indicators to measure the sustainability of the value chain.

Cold chain literature from a sustainability aspect examines the impact of transportation on the environment. The most widely used methods are heuristic and mathematical programming models. According to UNEP & FAO (2022), the development of a sustainable cold chain is not just about installing cooling technology but is also influenced by environmental, social, cultural, and political conditions. However, from the results of the literature review, the cold chain still predominantly studies economic aspects and rarely considers social aspects. However, in the Indonesian context, social aspects are quite important to consider in implementing the cold chain (Duggan & Kochen, 2016).

Cold chain management of the tuna agro-industry needs to be carried out in an integrated manner including economic, social, and environmental aspects. Issues regarding sustainability, especially commodity losses, need to be included in the cold chain management parameters of the tuna agro-industry One approach that can be used to integrate performance assessment and supply chain sustainability is the supply chain operation reference digital standard (SCOR DS) (ASCM, 2022).

Complex tuna agro-industry problems with high uncertainty require comprehensive evaluation criteria. Multi-criteria are needed to decide on solving the problem. Descriptive, mathematical programming, analytical, and heuristic methods are not enough to solve the tuna agro-industry problem. In the context of the tuna agro-industry cold chain with a high level of uncertainty, a more appropriate method is a simulation and analytical approach. The results of the study show that the hybrid method (analytical and simulation) has the lowest level of use (Table 6). This is a research gap.

The approach that can be used to solve problems that have hard and soft characteristics as in the tuna agro-industry is the soft system dynamic methodology approach. This approach is a combination of soft system methodology and system dynamics approaches (Rodriguez-Ulloa & Paucar-Caceres, 2005).

A potential form of research into cold chain design is the use of a soft system dynamic methodology approach in designing the tuna agro-industry cold chain as shown in Figure 8. In framework Figure 8, risks are analyzed using the house of risk (HOR), supply chain performance and sustainability performance are analyzed simultaneously with SCOR DS, and value chain strategies are analyzed using the analytical network process (ANP). Risk, performance, and sustainability integration models are analyzed using dynamic systems.

The integration of HOR, ANP, and system dynamics has several considerations. Variables analyzed using HOR, ANP, and system dynamics have the nature of a cause-and-effect relationship. The variable relationship in HOR is a causal relationship between the risk agent and the risk event. The variable relationship in ANP is a dependency relationship between variables. Variable relationships in system dynamics are also causal relationships (causal loops). This cause-and-effect relationship is very appropriate to the complex relationship that occurs in the cold chain management of tuna agro-industry. Cold chain management variables are based on a supply chain performance measurement approach using SCOR DS. SCOR DS has integrated performance measurement and sustainability measurement simultaneously.

Table 6 Comparison of methods used in cold chain analysis

Tabel 6 Perbandingan metode yang dipergunakan dalam analisis rantai dingin

| | % | | | |
|---|---|---|---|---|
| | Risk | Performance | Value Chain | Sustainability |
| Mathematical Programming | 10 | 0 | 0 | 23 |
| Simulation | 5 | 17 | 0 | 12 |
| Descriptive | 24 | 25 | 89 | 4 |
| Hybrid (analytical & heuristic) | 29 | 0 | 0 | 4 |
| Heuristic | 14 | 0 | 0 | 27 |
| Analytical | 19 | 33 | 0 | 4 |
| *Statistic* | 0 | 17 | 11 | 0 |
| Hybrid (analytical and simulation) | 0 | 8 | 0 | 0 |
| Experiment | 0 | 0 | 0 | 12 |
| Hybrid (mathematical programming and heuristic) | 0 | 0 | 0 | 15 |

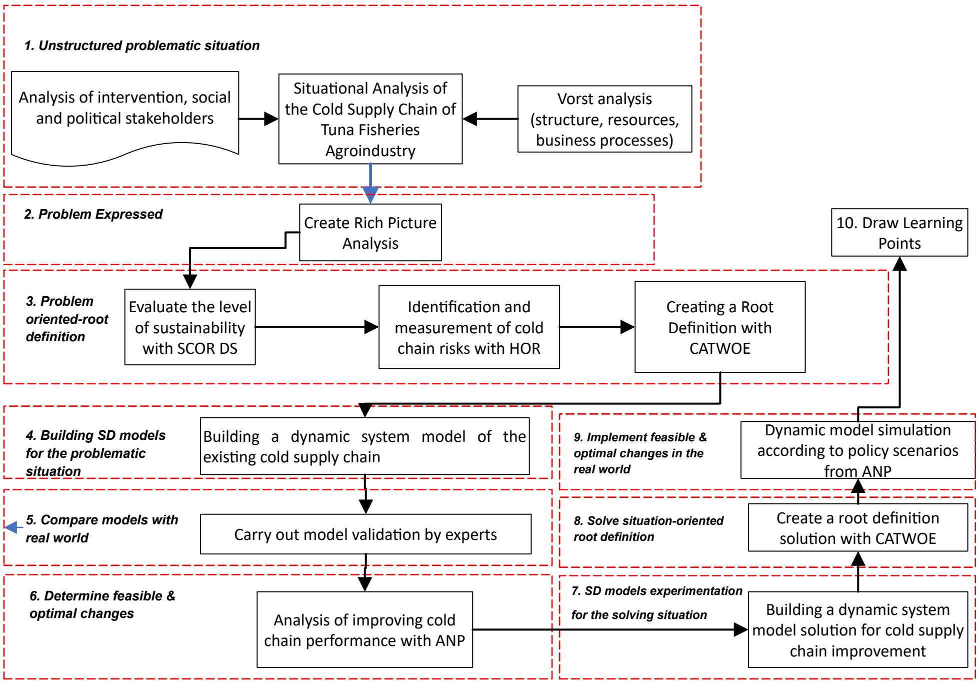


Figure 7 Framework for designing a tuna cold chain using a soft system dynamic methodology approach (SSDM)

Gambar 7 Kerangka kerja untuk merancang rantai dingin tuna menggunakan pendekatan *soft system dynamic metodology* (SSDM)

The results of this integrated approach provide input for the Government, tuna agro-industry, and fishermen. The government can use the results to develop a strategy for providing cold chain infrastructure for the tuna agro-industry. Agro-industrial companies and fishermen can build long-term cooperative relationships to improve sustainable supply chain performance.

## Future Research

Several other future research topics to follow up on the framework in Figure 7:

Standardization of cold chain implementation. Many perishable products require different handling, so far there is no standardization of the supply chain specifically for the cold chain. Supply chain standardization already exists, including ISO 28000. This standardization will make it easier to evaluate the effectiveness of cold chain implementation to maintain the quality of tuna fish.

Integration of cold chain implementation and monitoring from the catching stage (tuna) to the delivery of commodity products (tuna) to buyers. The process of unloading tuna from the ship to the port dock is critical because the cold chain is very likely to be broken. The absence of cold chain infrastructure at the port dock is the cause of the cold chain being broken.

Readiness for the complexity of implementing cold chain technology, especially in the small-scale fisheries industry. Handling tuna on board a ship is the most critical stage so it is necessary to apply several standards including good fish handling methods on board, monitoring the temperature of fish storage areas, and HACCP. Apart from that, catches need to be documented so that the traceability mechanism can work. Implementation of these standards requires information system support.

Utilization of cold chain temperature monitoring with information systems. The distribution and transportation stages are one of the critical stages of the cold chain. Generally, companies will use third parties to send products to buyers. During the delivery stage, many things will affect the temperature stability inside a refrigerated vehicle. Information technology is needed to monitor temperature stability.

Evaluation of the impact of cold chain implementation, especially on the environment due to carbon emissions from energy consumption for transportation and storage. The use of refrigerated technology requires large energy resources. Energy consumption will have an impact on the environment. Apart from evaluating the impact, safer and more environmentally friendly alternative energy is also needed.

## CONCLUSION

In most of the literature in the Indonesian context, analyzing the tuna supply chain still predominantly separates the cold chain phase on the on-farm (catching) and value chain analysis from the tuna agro-industry side to the consumer (off-farm). Apart from that, the literature still separates supply chain performance from sustainability performance. This influences the methods and approaches used to analyze cold chain issues in terms of risk, performance, value chain, and sustainability. The methods often used in cold chain research related to risk, performance, value chain, and sustainability aspects are descriptive and hybrid (analytical & heuristic), descriptive and analytical, descriptive, and heuristic and mathematical programming models. The use of these methods is not enough to solve the tuna agro-industry problem. Some methods that are rarely used are dynamic systems and soft systems methodology. This study proposes the framework for integrating soft and hard system issues from the tuna agro-industry cold chain. This literature review can help in analyzing the methods used to increase the effectiveness and efficiency of tuna agro-industry supply chain management and future steps. As a recommendation, the development of a tuna agro-industry decision support system needs to be studied further.

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