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A Study of Full Container Load (FCL) and Less than Container Load (LCL) Bookings to Assess the Feasibility of Developing Temperature-Controlled LCL Container Booking Software for International Shipping

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Abstract

This research aimed to (1) study the booking process of full container load (FCL) and less-than-container load (LCL) shipments, and (2) analyze the feasibility of developing a temperature-controlled LCL container booking software for international maritime exports. A mixed-methods research design was employed, integrating quantitative and qualitative approaches. The quantitative phase involved a survey of 393 respondents, while the qualitative phase included in-depth interviews with 18 key informants. The research instruments were validated for reliability and validity. Data were analyzed using descriptive statistics and content analysis. The findings revealed that respondents placed high to very high importance on product quality control factors, particularly types of temperature-sensitive goods ($\bar{X} = 4.60$) and required temperature levels ($\bar{X} = 4.52$). Other factors such as container size, transport duration, and route were rated as “high” (overall booking factors $\bar{X} = 4.29$). Regarding the feasibility of developing the LCL Reefer platform, the overall assessment was also at a “high” level ($\bar{X} = 4.31$), with the highest scores in software development feasibility ($\bar{X} = 4.50$) and market and customer potential ($\bar{X} = 4.47$). These results indicate strong commercial opportunities and technological readiness within the country. Qualitative findings supported the quantitative results, suggesting that the proposed LCL Reefer platform could reduce logistics costs for small and medium-sized exporters, increase booking flexibility, and enhance transparency through the integration of IoT and real-time tracking, container space consolidation, and data connectivity with ports and shipping lines via API. Experts also agreed that developing domestic software would help reduce dependence on foreign booking platforms and strengthen Thailand’s digital capability. In conclusion, the study confirms that developing a temperature-controlled LCL container booking platform in Thailand is technically and commercially feasible. It addresses the needs of temperature-sensitive export markets and offers potential for commercialization while contributing to green logistics policies and promoting national digital sovereignty in maritime transport technology.

Keywords: Full Container Load (FCL), Less than Container Load (LCL), Feasibility of Developing LCL Container Booking Software

1. Introduction

International maritime transport plays a vital role in driving both the global and Thai economies, as it supports the movement of large volumes of goods at a significantly lower unit cost compared with air or land transportation, while also connecting major port networks worldwide (UNCTAD, 2023). Containerization particularly the use of refrigerated containers (reefer containers)—has been a key innovation in maintaining product quality during transport, especially for perishable goods such as fresh food, pharmaceuticals, and chemicals (Notteboom & Rodrigue, 2020). However, the current container booking system remains limited to Full Container Load (FCL) services, which are suitable only for exporters with sufficient cargo to fill an entire container. Small and medium-sized enterprises (SMEs) with partial loads often face disproportionately higher unit costs or lack access to reefer container services altogether (Marine Department, 2022). This limitation affects the competitiveness of Thai exporters and leads to inefficient utilization of transport resources—both in terms of energy consumption, carbon emissions, and container management within international logistics systems (World Bank, 2022).

To address these logistical challenges, the concept of developing a Less than Container Load (LCL) booking software specifically for reefer containers has been proposed. The goal is to create a system that efficiently matches multiple exporters to share a single container through advanced scheduling, shared-temperature calculation, and real-time tracking technologies (Lee et al., 2021). Such a system would significantly reduce shipping costs for small exporters, increase market opportunities, and enhance the competitiveness of Thai businesses in the international logistics sector (Kasemsap, 2020). Moreover, the development of a digital LCL platform aligns with Thailand's Digital Economy Policy and contributes to reducing greenhouse gas emissions by improving the efficiency of container utilization (Office of Energy Policy and Planning, 2023). At present, there is still a lack of in-depth studies on the development of a temperature-controlled LCL container booking system, which represents a critical research gap that warrants further exploration and development. Addressing this gap will enable the creation of a practical and commercially viable model that strengthens Thailand's logistics capacity and trade resilience at the national level.

1.1 Research Objective

This study was conducted with the following objectives:

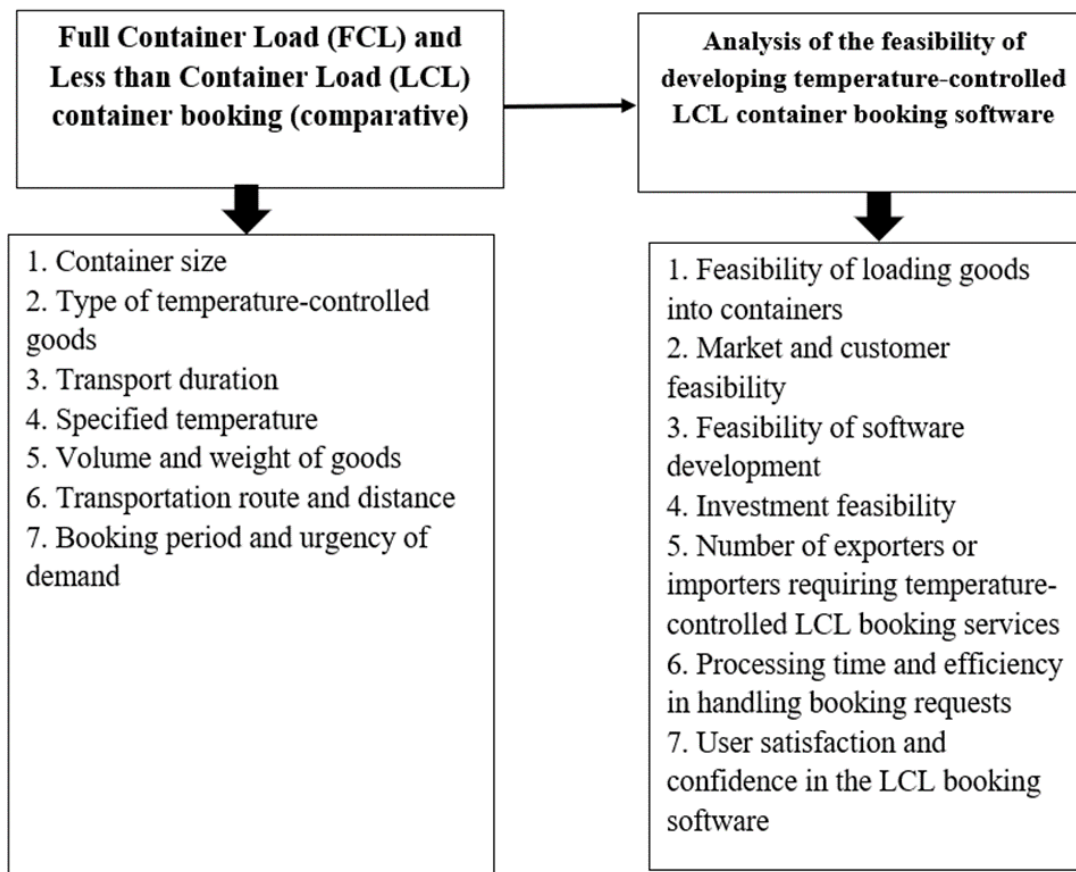
1. To examine the booking processes of Full Container Load (FCL) and Less than Container Load (LCL) shipping in international maritime transport.

2. To analyze the feasibility of developing temperature-controlled LCL container booking software for international maritime export operations.

2. Literature review

Conceptual Framework

This research is developed based on the conceptual foundation of Wang et al. (2024); Xu et al. (2022); J. Mar. Sci. Eng. (2025); Hapag-Lloyd (2024); ORBCOMM (2024); Mandal et al. (2022); Zhong et al. (2023)



2.1 Container Booking

Container booking is an essential and indispensable step in the maritime shipping process, as shippers must reserve containers and vessel space in advance from carriers or freight forwarders to ensure timely shipment and to prevent container shortages during high-demand periods (Wang et al., 2024). Advance booking is therefore crucial for guaranteeing container availability and allowing exporters to plan inventory management and shipping schedules efficiently, which are key factors in reducing logistics costs and improving operational performance in export businesses (Xu et al., 2022). In addition, container booking plays a significant role in the management of maritime logistics resources by balancing the supply and demand of containers across shipping routes (Guo et al., 2021). Efficient booking management enables shipping lines to forecast container demand accurately, which is vital for vessel capacity planning and global container repositioning (J. Mar. Sci. Eng., 2025). Furthermore, the integration of digital booking systems enhances data management transparency and traceability among shippers, freight forwarders, and shipping lines. This aligns with the Smart Maritime Logistics initiatives currently being implemented in many countries (Zeng, 2021).

Moreover, container booking is directly related to the revenue management of shipping lines, as booking data can be used to forecast shipment volumes, optimize vessel capacity utilization, and set freight rates according to market conditions and seasonal demand (Guo et al., 2021; Wang et al., 2024). Therefore, efficient management of the container booking process is a strategic component that directly affects the competitiveness of shipping lines, exporters, and the overall maritime transport system both nationally and globally.

2.2 Software Development

The development of software for temperature-controlled Less than Container Load (LCL) container booking in Thailand represents an integration of Internet of Things (IoT) technologies with the agricultural product supply chain to enable real-time, precise, and efficient monitoring and control of container environments (Hapag-Lloyd, 2024; ORBCOMM, 2024). This system allows exporters to track temperature, humidity, and shipment locations continuously, reducing the risk of spoilage or quality degradation of agricultural and pharmaceutical products factors essential for enhancing the competitiveness of Thai exporters in the global market. The software development process encompasses three fundamental components: process, method, and tools. The process defines workflow sequences, the method specifies problem-solving techniques such as multi-zone temperature control and cargo consolidation from multiple exporters in a single container—and the tools include IoT sensor hardware, cloud-based data processing software, and API or web applications for real-time user access (Nexxiot, 2024). Furthermore, the incorporation of the Multi-Agent System (MAS) framework has emerged as an advanced approach to managing container booking and vessel slot allocation. Recent studies have demonstrated the design of autonomous agent architectures capable of real-time communication between exporters, freight forwarders, and shipping lines to improve booking accuracy, acceptance/rejection management, and slot allocation flexibility (Mandal et al., 2022). Overall, the integration of IoT and MAS technologies in the development of an LCL Reefer booking system can expand accessibility for small and medium-sized exporters, reduce inefficient full-container usage, optimize container resource utilization, and promote a sustainable upgrade of Thailand's agricultural export supply chain.

2.3 International Logistics Management

International logistics management refers to the systematic planning and coordination of activities to efficiently meet global market demands in terms of both time and cost, including transportation route selection, inventory management strategies, and the choice of appropriate logistics service providers (Song & Dong, 2024). In the context of maritime transport—where containerization serves as the core mechanism—the integration of activities among exporters, freight forwarders, shipping lines, ports, and internal logistics services forms the backbone of international logistics management (Song, 2023). Furthermore, information and communication technologies, such as real-time tracking systems and the Internet of Things (IoT), play a vital role in enhancing transparency and operational efficiency in maritime container transportation by reducing waiting times, minimizing errors, and improving supply chain agility on a global scale (Zhong et al., 2023). Another essential dimension is risk management, which addresses uncertainties related to maritime transport such as fluctuating costs, weather conditions, port congestion, and global market volatility. Effective logistics management requires proactive risk assessment and mitigation strategies, including insurance arrangements, historical data analysis, and stakeholder collaboration within the supply chain (Huang & Xu, 2022). In the context of sustainability, international logistics management

through maritime container shipping also contributes significantly to reducing greenhouse gas emissions and improving energy efficiency (World Economic Forum, 2023). The integration of digital and IoT technologies enables route optimization, resource efficiency, and sustainable logistics operations (MDPI *Sustainability*, 2023). Finally, fostering collaboration and mutual understanding among exporters, logistics service providers, and shipping lines is crucial in minimizing conflicts within the international supply chain and enhancing the overall performance and resilience of global logistics systems (Martin-Navarro et al., 2023).

3. Methodology

This study employed a mixed-methods research design, combining both quantitative and qualitative approaches. The population consisted of 23,100 individuals, including employees of frozen and chilled goods export companies that are members of the Thai Frozen Foods Association (TFFA), and freight forwarding companies that are members of the Thai International Freight Forwarders Association (TIFFA). A total of 393 respondents were selected as the sample group, determined using Yamane’s (1973) formula at a 95% confidence level and 5% margin of error. For the qualitative phase, 18 key informants were selected for in-depth interviews, consisting of executives or employees with at least three years of work experience in logistics or export operations. The research instruments included a structured questionnaire and a structured interview form. The questionnaire’s content validity was verified by experts, yielding an IOC (Index of Item-Objective Congruence) value of 1.0, and its reliability was confirmed with a Cronbach’s Alpha coefficient of 0.86. Data collection was conducted over a period of two months. The quantitative data were analyzed using descriptive statistics, including mean (\bar{X}), standard deviation (SD), and ranking of importance, while the qualitative data were analyzed using content analysis to interpret and synthesize insights from the in-depth interviews.

4. Results

Quantitative findings are summarized in Tables 1 and 2.

Table 1. Mean and Standard Deviation of Factors in Full Container Load (FCL) vs. Less than Container Load (LCL) Booking (Comparative)

No.	Assessment Item	\bar{X}	SD	Interpretation	Rank
1	Container size	4.35	0.52	High	3
2	Type of temperature-controlled goods	4.60	0.49	Very High	1
3	Transport duration	4.21	0.64	High	5
4	Specified temperature	4.52	0.57	Very High	2
5	Volume and weight of goods	4.28	0.63	High	4
6	Transportation route and distance	4.09	0.71	High	6
7	Booking period and urgency of demand	3.98	0.78	Moderate	7
Overall mean		4.29	0.62	High	

Table 2. Mean and Standard Deviation of Factors Related to the Feasibility of Developing Temperature-Controlled LCL Container Booking Software

No.	Assessment Item	\bar{X}	SD	Interpretation	Rank
1	Feasibility of loading goods into containers	4.31	0.58	High	4
2	Market and customer feasibility	4.47	0.51	Very High	2
3	Feasibility of software development	4.50	0.49	Very High	1
4	Investment feasibility	4.24	0.67	High	5
5	Number of exporters or importers requiring temperature-controlled LCL booking services	4.40	0.55	High	3
6	Processing time and efficiency in handling booking requests	4.05	0.70	High	6
7	User satisfaction and confidence in the LCL booking software	4.19	0.66	High	7
Overall mean		4.31	0.59	High	

Quantitative Summary (from Tables 1 and 2). The highest mean scores were observed for software development feasibility and market and customer feasibility, indicating strong technological readiness and clear commercial opportunities for developing an LCL reefer booking system. Overall, respondents rated both domains at a high level: the aggregate mean for FCL/LCL booking factors was $\bar{X} = 4.29$ (SD = 0.62), and the aggregate mean for feasibility of developing the LCL reefer software was $\bar{X} = 4.31$ (SD = 0.59). These results suggest that Thailand’s export industry is favorably positioned to advance a temperature-controlled, less-than-container-load booking platform, thereby expanding SMEs’ access to reefer services and reducing maritime logistics costs.

Qualitative Research Findings

1. Export Industry Demand: Thai exporters, particularly SMEs, demonstrated strong demand for temperature-controlled LCL shipping services to reduce transportation costs for partial loads and to increase scheduling flexibility. This finding aligns with the quantitative result showing a high mean score ($\bar{X} = 4.29$), particularly for the factors “*type of temperature-controlled goods*” and “*specified temperature,*” which were ranked as the most critical. These results highlight that maintaining product quality is the key determinant in choosing reefer container services, whether for full or partial loads.

2. Technical Feasibility and Platform Development: Qualitative analysis from logistics and IT experts indicated a high level of feasibility for developing such a platform ($\bar{X} = 4.31$). Thailand’s strong digital infrastructure—including IoT and cloud computing—can be effectively utilized for real-time tracking of temperature, location, and shipment conditions. Furthermore, the system can directly integrate with port authorities, shipping lines, and logistics providers via API or web portals, enhancing transparency and reducing documentation costs.

3. Business and Investment Feasibility: Shipping service providers and investors recognized strong business potential for the LCL Reefer platform, noting that the domestic market gap for small-scale temperature-controlled shipping remains largely unaddressed. Most operators still rely on international platforms such as INTTRA and Maersk Spot, which are costly and less

accessible for SMEs. Developing a domestic platform could foster competition within the logistics sector, prevent revenue outflow, and strengthen Thailand's digital and technological capabilities.

4. Sustainability and Logistics Collaboration: The LCL Reefer platform aligns with Thailand's *Digital Economy* and *Green Logistics* policies, contributing to greenhouse gas reduction by improving container space utilization efficiency. It also promotes energy-efficient transport operations. Moreover, integrating data among exporters, freight forwarders, and shipping lines can create a collaborative digital logistics ecosystem that supports long-term sustainability in the supply chain.

5. User Acceptance and Confidence: Exporters and importers expressed positive attitudes toward the LCL Reefer booking platform concept, emphasizing its accessibility, convenience, and transparency. Real-time shipment tracking and automated cost calculation were cited as features that enhance trust and confidence, particularly among small and medium-sized exporters.

Summary: Overall, the findings indicate that developing a temperature-controlled LCL container booking platform in Thailand is feasible across all dimensions—technological, market, and investment. The system also possesses strong potential for commercial scalability, as it can integrate with major logistics providers and establish a national standard for digital reefer booking services, thereby reducing reliance on foreign software, advancing Thailand's digital economy, and enhancing the long-term competitiveness of its export industry.

5. Conclusion

This study aimed to compare the factors influencing Full Container Load (FCL) and Less than Container Load (LCL) container booking, as well as to analyze the feasibility of developing a temperature-controlled LCL container booking software platform (LCL Reefer) to support international maritime transportation in Thailand.

The quantitative results revealed that the most influential factors in container booking were the type of temperature-controlled goods ($\bar{X} = 4.60$) and the specified temperature ($\bar{X} = 4.52$). These findings align with the characteristics of Thailand's key export products—such as frozen foods, fresh fruits, and pharmaceuticals—which require strict temperature control throughout the shipping process. Other factors, including container size, transportation duration, and route, were rated at a “high” level, indicating exporters' strong awareness of product quality and safety as top priorities in logistics operations. Regarding the feasibility of developing the LCL Reefer software platform, the overall mean score was also at a “high” level ($\bar{X} = 4.31$, S.D. = 0.59). The highest mean values were found in software development feasibility ($\bar{X} = 4.50$) and market and customer feasibility ($\bar{X} = 4.47$), reflecting both favorable business opportunities and technological readiness within the country.

The qualitative findings, based on interviews with experts in logistics, information technology, and export operations, further confirmed that Thailand possesses the necessary potential for platform development—supported by robust digital infrastructure, strong market demand, and capable IT professionals. Additionally, the development of a domestic system would reduce reliance on expensive foreign platforms such as *Maersk Spot* and *INTTRA*, which often fail to accommodate the needs and contexts of small and medium-sized Thai exporters (SMEs).

Overall, the study concludes that Thailand is well-positioned to develop and commercialize a temperature-controlled LCL booking platform, which could strengthen national logistics capacity, enhance technological independence, and boost the competitiveness of Thailand's export sector in the global maritime trade system.

5.1 Discussion

The findings align with Song and Dong (2024), who argue that international logistics management in the digital era relies on digital technologies, IoT, and smart logistics to enhance system efficiency and transparency. Consistent with this view, the present study shows that Thai exporters place strong emphasis on real-time temperature monitoring and control. Moreover, the use of IoT sensor data to track cargo conditions inside reefer containers is corroborated by Zhong et al. (2023) and Setthachotsombut et al. (2024), who describe the transition toward digital maritime logistics as a means to reduce delivery risks and strengthen the reliability of service providers.

Technological and Software Feasibility: The findings support the propositions of Hapag-Lloyd (2024) and ORBCOMM (2024) that the application of IoT and cloud technologies in reefer container management is a highly effective approach for monitoring cargo conditions. This is particularly beneficial when applied to LCL systems, which require the simultaneous management of multiple types of goods within a single container. Moreover, the concept of utilizing a Multi-Agent System (MAS) to manage booking requests and vessel slot allocation, as proposed by Mandal et al. (2022), is consistent with this study's aim to develop a platform capable of processing multiple booking transactions concurrently and controlling zoned temperature management within an integrated system.

Novel Contribution: The distinctive and novel contributions of this research are as follows:

1. Development framework tailored to the Thai export context – This study proposes a practical framework for developing an LCL Reefer booking platform specifically aligned with the needs of Thai exporters, particularly SMEs, which has never been systematically investigated in Thailand before.
2. Integration of quantitative and qualitative findings – By combining quantitative analysis with qualitative insights, the research provides a comprehensive understanding of both market demand and technological readiness, offering a holistic perspective for platform development.
3. Advancing digital sovereignty – The study highlights that developing a domestic LCL Reefer booking platform can effectively reduce Thailand's dependence on foreign software systems and serve as a strategic step toward strengthening the nation's digital sovereignty and technological independence.

Policy and Commercial Implications

The results also indicate that promoting the domestic development of an LCL Reefer platform would help establish a more efficient and sustainable maritime logistics system, aligning with Thailand's Digital Economy and Green Transport policies (World Economic Forum, 2023; Martin-Navarro et al., 2023). With proper support from both the public and

private sectors, the platform could be commercially scalable, serving not only as a tool to enhance exporters' competitiveness but also as a digital infrastructure that elevates the national logistics industry. Overall, the study confirms that Thailand possesses strong technological, economic, and market potential to develop and implement a temperature-controlled LCL container booking platform domestically. Such a system represents a sustainable solution for cost reduction, logistics efficiency improvement, and reduced dependency on foreign software, ultimately driving Thailand toward innovative, globally competitive maritime logistics.

5.2 Recommendations

Practical Recommendations

1. **Commercial Platform Development:** Government and private sectors should collaborate to promote the commercial implementation of the "LCL Reefer Booking System" software platform. In particular, partnerships among the Marine Department, the Department of International Trade Promotion, and maritime logistics service providers are crucial to ensure that Thai exporters can access temperature-controlled shipping services at affordable rates. This would also reduce dependency on foreign booking systems such as *Maersk Spot* or *INTTRA*.
2. **Support for SMEs:** The government should establish financial and technical assistance programs (Technology Subsidy) for small and medium-sized exporters (SMEs) to encourage the adoption of the LCL Reefer system. Such initiatives may include training programs, system integration with port databases, and temporary software license subsidies to facilitate platform adoption during the initial stages.
3. **National Logistics Data Integration:** The LCL Reefer booking platform should be connected with the Smart Port system and electronic customs system (e-Customs) to enable automated, transparent, and traceable international shipping processes. This integration aligns with the Digital Maritime Logistics framework recommended by the World Trade Organization (WTO) and UNCTAD, promoting efficiency and interoperability in global logistics.
4. **Policy Application for Green Logistics:** Since the LCL Reefer system reduces excessive energy use and greenhouse gas emissions, the research findings can be applied to support green logistics policies in line with the IMO's Carbon Neutral Shipping 2050 target. Implementing this system would contribute directly to Thailand's transition toward sustainable and environmentally responsible maritime operations.
5. **Application in Education and Knowledge Development:** Higher education institutions and logistics research centers can adopt the conceptual model and methodological framework from this study as a case study for programs in logistics, supply chain management, or software development. This will enhance understanding of how digital technologies can be integrated with maritime logistics systems and foster innovation in logistics education and practice.

5.3 Recommendations for Future Research

1. **Development of a System Simulation Model:** Future research should focus on developing a simulation model to test the operational efficiency of the LCL Reefer booking platform under real-world conditions. This should include simulations of container space allocation, shared temperature calculations, and system responsiveness to a high volume of simultaneous booking requests.
2. **Economic Impact Analysis:** Further studies should conduct an economic impact assessment of the LCL Reefer booking platform to evaluate its effects on logistics costs, exporters' competitiveness, and macroeconomic benefits such as reductions in unit shipping costs and increases in export value.
3. **User Experience and Behavior Study:** Future research should include surveys or field experiments to investigate user satisfaction, technology acceptance, and usage behavior among exporters. This will help refine the platform's user interface and functionality to better meet users' needs.
4. **Integration of Advanced Technologies:** Expanding the research scope to include AI, Blockchain, and Big Data Analytics could provide valuable insights into container demand forecasting, automated route planning, and data security management in the booking process.
5. **Comparative Study within ASEAN:** A comparative study among ASEAN countries—such as Singapore, Vietnam, and Malaysia—should be undertaken to identify key success factors, best practices, and region-specific challenges related to LCL Reefer booking systems. This would help derive practical policy recommendations suitable for Thailand's logistics context.

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