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Effect of Modular Container Design and Load Consolidation Strategy on Cargo Operational Efficiency

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Abstract : The modern logistics industry faces significant challenges in improving operational efficiency amid cost pressures, increasing demands for flexibility, and stringent environmental regulations. This study aims to explore the impact of modular container design and cargo consolidation strategies on cargo operational efficiency. Using a literature review approach, the findings reveal that modular container design increases flexibility and efficiency in space utilization, accelerates loading and unloading processes, and reduces the number of containers required. On the other hand, cargo consolidation strategies integrate multiple shipments into a single delivery to minimize delivery frequency, lower fuel consumption, and reduce carbon emissions. The integration of these two approaches provides a holistic solution for improving logistics efficiency while supporting environmental sustainability. These findings offer strategic insights for logistics industry stakeholders to adopt innovations that boost competitiveness and ensure sustainable operations.

Keywords: Modular Container Design, Cargo Consolidation, Operational Efficiency, Sustainable Logistics, Emission Reduction .

INTRODUCTION

The modern logistics industry continues to grow rapidly along with the increasing global demand for efficient, fast and environmentally friendly goods delivery. The challenges faced by this sector are increasingly complex, especially in managing the distribution of goods amidst the pressure of high operational costs, the need for flexibility, and increasingly stringent environmental regulations. In this context, cargo operational efficiency is one of the key elements that must continue to be optimized to maintain the competitiveness and sustainability of logistics companies.

One of the innovations that emerged to answer these challenges is the modular container design. With the flexibility offered, modular containers allow for the optimization of storage space usage, speed up loading and unloading processes, and support operational adjustments based on specific needs in the field. Modular containers not only increase storage efficiency but also have a positive impact in reducing space waste and operational costs. This is very relevant in facing the increasing complexity of cargo shipping, especially in dense international distribution channels.

In addition to container design, cargo consolidation strategies are also an important approach to improving logistics operational efficiency. This strategy involves combining different types of cargo in one shipment to reduce shipping frequency, minimize fuel costs, and reduce carbon emissions. Cargo consolidation provides significant economic and environmental benefits, especially amidst the growing global awareness of the importance of more sustainable logistics operations.

Although both approaches have been recognized as strategic solutions, research on the relationship between modular container design and cargo consolidation strategies in the context of operational efficiency is still limited. Most existing studies tend to discuss the two separately, thus not providing a comprehensive picture of how the integration of these two elements can create a more effective logistics system.

With this background, this journal aims to explore the influence of modular container design and cargo consolidation strategies on cargo operational efficiency. This research is expected to contribute to filling the literature gap while offering practical solutions that can be applied by logistics industry players to improve efficiency, reduce costs, and support operational sustainability in an increasingly competitive era of globalization.

METHOD

This study uses a qualitative method with a literature study approach to explore the influence of modular container design and cargo consolidation strategies on cargo operational efficiency. Primary data sources in the form of journals, scientific articles, and industry reports relevant to the theme are analyzed through coding and categorization techniques to identify key themes related to the research variables. The analysis process is carried out by matching findings from various sources to ensure data validity, as well as compiling data synthesis to provide a comprehensive picture of the relationship between modular container design and cargo consolidation on cargo operational efficiency. The main objective of this study is to provide an in-depth understanding of how both elements contribute to improving operational efficiency, as well as identifying factors that influence success in the context of the modern logistics industry.

RESULTS AND DISCUSSION

1. Modular Container Design and Flexibility of Cargo Use

Modular container design according to (Prawata, nd) allow more efficient and flexible use of space, reducing space waste in each container unit . This modular design allows containers to be adjusted to different sizes and shapes of cargo, significantly increasing storage capacity. The main advantage of this system is its ability to optimize the use of available space by minimizing empty space, which has often been a problem in cargo transportation.

In addition, the modular system can increase flexibility in cargo arrangement because each container unit can be changed in configuration or internal dimensions, adjusted to the type of cargo to be transported. This simplifies the *loading* and *unloading process*, which is often a weak point in cargo transportation operations. With a more organized space, the time required for the loading and unloading process can be minimized, providing time efficiency that has an impact on reducing operational costs.

In practice, the application of modular container design can reduce the number of containers required in a single shipment. Because each container unit can be optimized to its maximum capacity, logistics companies do not need to use more containers to transport the same volume. This certainly reduces transportation costs related to the procurement of containers and fuel used during transportation. In addition, by reducing wasted space in containers, modular systems also contribute to reducing carbon emissions, making them a more environmentally friendly option.

2. Cargo Consolidation Strategy in Improving Operational Efficiency

According to the results of research conducted by (Arryanda Maulani Laut & Kelautan, 2016), an efficient cargo arrangement strategy in a consolidation warehouse can have a significant impact on increasing operational productivity and accelerating the distribution of goods. Optimizing cargo arrangement allows the time required for the loading and unloading process to be minimized. In addition, this strategy contributes directly to reducing logistics costs through maximum utilization of storage capacity. This cost reduction is achieved by reducing unproductive empty space in storage and reducing shipping frequency, allowing companies to allocate resources more effectively.

In the context of cargo shipping, implementing a well-designed cargo consolidation strategy has been proven to reduce operational costs, speed up delivery times, and streamline the flow of goods from producers to consumers. This strategy not only helps companies meet distribution targets faster, but also creates added value in the overall supply chain. Well-planned consolidation ensures that each shipment journey delivers maximum impact, both in terms of space, time, and cost efficiency.

Further research by Handayani et al. (2023) also confirmed that the consolidation approach to shipping plays an important role in improving supply chain efficiency, especially in the food supply chain. In the study, consolidation of shipments involving various types of products allows for the optimization of the transportation fleet and significant reduction in shipping costs. This principle can be applied more widely in cargo transportation in various sectors, including large-scale logistics and international trade. By combining small shipments into one large shipment, cargo consolidation can reduce the need for separate shipments, which ultimately saves resources, both in the form of fuel and time.

One of the main advantages of a consolidation strategy is its ability to integrate cost efficiency with environmental sustainability. By reducing the frequency of travel, carbon emissions generated during the logistics process can be significantly reduced. This is in line with global initiatives to reduce the negative impact of the logistics sector on the environment. In the long term, this approach not only supports the company's sustainability goals but also creates a positive image in the eyes of consumers who are increasingly concerned about environmental issues.

The consolidation approach also has the added benefit of reducing traffic congestion in urban areas, which is often a major challenge in logistics distribution. By reducing the number of trips taken, freight consolidation helps reduce pressure on transportation infrastructure and minimizes disruption to local communities. In addition, this strategy allows companies to leverage more sophisticated logistics management technologies and systems, such as route optimization algorithms and automated scheduling systems, to support more efficient operations.

However, implementing a cargo consolidation strategy also faces its own challenges. Effective coordination between various parties in the supply chain, such as suppliers, distributors, and logistics service providers, is a key factor in the success of this strategy. In addition, initial investment is required in supporting infrastructure and technology, such as consolidation centers, warehouse management systems, and transportation fleets specifically designed to support large volume shipments.

3. The Impact of Large-Scale Cargo Consolidation

Large-scale cargo consolidation strategies are an increasingly relevant approach to addressing the challenges of the modern logistics industry. With increasing pressure on operational costs, the need for efficiency, and the demands of environmental sustainability, cargo consolidation offers a comprehensive solution. In its implementation, this strategy aims

to maximize the use of container capacity, ensuring that each shipment journey not only carries goods but also operational efficiency at every stage of the logistics process.

As a concrete step, optimization methods such as those used in the *Benders Decomposition approach* (Hanbazazah et al., 2018) have proven their ability to significantly reduce operational costs. This technique works on the principle of dividing complex logistics problems into smaller subproblems, which are then solved iteratively to find the optimal solution. By utilizing container capacity to its full potential, this approach ensures that no space is wasted in the shipping process, ultimately increasing the economic value of each trip.

One of the keys to the success of this consolidation strategy is the ability to adapt to fluctuations in cargo volume. In the context of large-scale logistics, cargo volumes can vary depending on the season, market demand, or consumption patterns. Therefore, flexibility in adjusting container capacity to cargo volume becomes essential. This adjustment not only avoids wasting space but also has a direct impact on reducing the frequency of trips required. In this case, the consolidation strategy contributes to transportation cost efficiency, reducing fuel consumption, and shortening delivery times.

From an environmental sustainability perspective, large-scale cargo consolidation has a very positive impact. By reducing the number of trips, this strategy helps reduce carbon emissions generated by logistics activities. In the long term, this emission reduction not only supports global sustainability initiatives but also improves the company's image in the eyes of increasingly environmentally conscious consumers. This strategy is also relevant in meeting increasingly stringent government regulations regarding carbon emissions and energy efficiency in the logistics sector.

In addition, the cargo consolidation strategy provides strategic advantages for logistics companies in increasing competitiveness. The integration of cost efficiency, time, and environmental sustainability creates significant added value in the company's operational system. In large-volume shipping scenarios and complex routes, this strategy provides a structured solution that can be applied to various logistics business models.

A large-scale cargo consolidation strategy is not just a technical approach but also an operational philosophy. It requires collaboration between various parties in the supply chain to ensure its success, from transportation providers to customers. When implemented properly, cargo consolidation can be a key pillar in creating a more efficient, environmentally friendly and sustainable logistics system.

4. Integration of Modular Container Design and Load Consolidation in Cargo Shipping

Integrating modular container design with cargo consolidation strategy is a strategic move that can revolutionize logistics operations, especially in facing the challenges of cargo management in dense urban areas. The modular design of containers not only provides flexibility in transporting various types of cargo, but also allows for more optimal space management. Containers with adjustable dimensions ensure that no space is wasted, so that vehicle capacity can be fully utilized.

The cargo consolidation strategy is an ideal companion to this modular design. By combining cargo from multiple shippers into one trip, cargo consolidation eliminates the need for partial shipments that are often wasteful in terms of fuel, time and labor. In practice, this not only saves operational costs but also makes a significant contribution to reducing carbon emissions, which are an increasing concern in the modern era.

This integration becomes even more relevant in *megacity environments*, where shipping demand is increasing rapidly, while challenges such as traffic congestion and infrastructure constraints continue to loom. The use of modular containers designed to accommodate different types of goods can speed up the transportation process while reducing waiting times at distribution points. This strategy also provides flexibility in shipping routes, allowing logistics

companies to adapt to dynamic traffic conditions and avoid delays that can be detrimental to customers.

From a long-term perspective, the integration of modular design and cargo consolidation is not only a technical solution, but also part of a broader sustainability strategy. By reducing the number of vehicles required to transport goods, companies not only save on operational costs but also reduce the carbon footprint left by their logistics activities. This step is important in building a company's reputation as an environmentally responsible entity.

Such a system not only increases logistics efficiency but also improves the dynamics of the supply chain as a whole. However, the successful implementation of this strategy requires careful planning, investment in the right technology, and training of human resources to ensure the system can run optimally. From the author's perspective, this approach should be considered as part of a comprehensive transformation in the logistics sector, which focuses not only on cost efficiency but also on the sustainability and resilience of the system amidst the challenges of globalization.

5. Technology Implementation in Modular Container Design and Cargo Consolidation

Technological developments in the logistics industry are accelerating the adoption of modular container designs and cargo consolidation strategies. With the advent of Internet of Things (IoT), artificial intelligence (AI), and advanced data analytics, container management and route and load optimization have become more effective.

IoT enables real-time monitoring of container conditions, including temperature, humidity, and cargo position, which is critical for industries that handle sensitive products such as pharmaceuticals and food. IoT-connected sensor technology can provide real-time data to logistics operators to ensure that shipping conditions remain optimal. In addition, IoT systems also enable early identification of potential risks, such as abnormal temperature changes or leaks in containers, allowing for quick corrective action.

Meanwhile, AI and machine learning are used to analyze shipping patterns and optimize consolidation strategies to reduce costs and increase distribution speed. AI algorithms can automatically calculate the best load combination based on volume, weight, and destination of the shipment, ensuring optimal use of space in the container. Thus, AI helps reduce the need for inefficient trips and optimize the use of the transportation fleet.

In addition to IoT and AI, the implementation of blockchain in logistics further increases the transparency and security of data in the supply chain. By using blockchain technology, every transaction and movement of cargo can be recorded in an immutable system, reducing the risk of fraud and administrative errors. Blockchain also allows for better coordination between various parties in the supply chain, including suppliers, distributors, and logistics service providers.

Other technologies that are increasingly being implemented include warehouse automation systems and autonomous vehicles. Warehouse automation systems use robots and advanced software to speed up the loading and unloading process and sorting of goods. This reduces reliance on manual labor and increases accuracy in the inventory management process. Meanwhile, autonomous vehicles and delivery drones are beginning to be tested in the logistics industry to improve the efficiency of short-haul deliveries and reduce transit times.

With the adoption of this technology, operational efficiency in logistics can be significantly improved. The use of this technology not only increases efficiency but also strengthens sustainability by reducing waste and excessive energy consumption. In the long run, the application of advanced technology in modular container design and cargo consolidation strategies will help create a smarter, more responsive and environmentally friendly logistics system.

CONCLUSION

The implementation of modular container design and cargo consolidation strategies increases operational efficiency, reduces costs, and supports environmental sustainability. Modular design maximizes space, speeds up loading and unloading, and reduces the number of containers used, thereby reducing transportation costs and carbon emissions.

The cargo consolidation strategy combines multiple shipments into one more efficient journey, saving fuel and time, and reducing trip frequency and carbon footprint. Its large-scale implementation optimizes container capacity and shipping efficiency in the global supply chain.

The integration of these two strategies creates a holistic logistics solution that enhances the company's competitiveness and supports sustainability. Its success depends on strategic planning, technology investment, and good human resource management.

The implementation of technologies such as IoT, AI, blockchain, warehouse automation, and autonomous vehicles further enhance the effectiveness of this strategy. Digital transformation in logistics not only improves operational efficiency but also creates a more sustainable, transparent, and resilient ecosystem to face global challenges.

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