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Integrating IoT and smart AI for Enhanced Sustainability in freight forwarding companies Performance

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Abstract

The following study investigates the role and impact of IoT and Al technologies on operational efficiency, sustainability, and cost optimization of freight forwarding companies. Their goals are to measure the effects of these technologies on logistics performance, assess sustainability improvements like decreased carbon emissions and waste, and identify cost-saving drivers for AI and IoT integration. H1: The operational efficiency of IoT and AI should enhance information sharing, route planning, and warehouse management significantly H2 claims that it will contribute to the reduction of carbon emissions and waste production by allowing real-time tracking, optimizing the usage of materials throughout the production cycle. H3- Cost Reduction in Logistics Operations through AI-based Automation, Predictive analytics and Improved Asset Management The approach was a quantitative research design, and data were obtained from 240 respondents from five large freight forwarders (companies): DHL Global Forwarding; Kuehne + Nagel; DB Schenker; XPO Logistics; and CEVA Logistics. Objective: Improvements after adoption are analyzed using structured questionnaires to measure key performance indicators (KPI) and frequency analysis and percentage calculation methods. The results confirm the transformative role of IoT and AI in freight logistics, increasing operational efficiency, sustainability, and cost efficiency. Logistics performance must be further optimized through continued investment in digital innovation.

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1. Introduction

The freight forwarding business is a crucial enabler of global trade and logistics, managing the complex movement of goods across varied geographies. Yet it also faces ongoing issues that need solving, such as cutting back on operational costs and increasing efficiency, and addressing environmental issues, such as carbon emissions and waste. Integrating IoT with AI is hence a game-changing solution to overcome these difficulties. When we apply this to the logistics sector, it means that the main players from the industry are using Internet of Things to collect and send data across connected devices in real-time thereby enhancing supply chain visibility & control [1, 2]. On the other hand, AI utilizes this data for informed, automated decisions by merging the core logistics functions, for example at routing, inventory tank, and demand forecasting [3]. This led to more resilient, responsive and efficient supply chains for organizations such as Walmart, etc. [4-6]. The combination of IoT and AI not only enhances operational efficiency by allowing for effective information flow and optimal usage of warehousing systems [7], but also increases sustainable efficiency through the reduction of carbon footprint by better routing and vehicle utilization [8-10]. This study focuses on how sustainability performance in freight forwarding firms, namely information sharing,

warehousing and routing performance, is impacted by these new technologies. In doing so, it unlocks the power of IoT and AI to reduce costs, enhance sustainability and reinvent logistics processes.

1.1 Information Sharing Efficiency

Efficient Share of Information is used in modern logistic, which is very relevant in case of IoT. By using IoT technologies, freight forwarding companies could gather and provide real-time data from multiple data sources including warehouses, transportation fleets, and suppliers. Having a constant flow of such data empowers more coordinated interactions with departments, partners and customers, establishing a scenario where decision-making is driven by data and performed in an agile manner. According to [11-13], having access to real-time data enables companies to identify and respond more quickly to disruptions like transportation delays and stock outs. Artificial intelligence AI also boosts this process by processing data functionally to facilitate better decision-making to keep stocks moving optimally and thus reduce delays [14]. According to [15-16], this better flow of information increases the responsiveness of supply chains, allowing them to quickly adapt to changes in the market. That results in tremendous increases in operational efficiencies and in customer experience.

1.2 Warehousing Optimization

The IoT and AI technologies rolling out to warehouse operations provide customers with rich, data-driven insights on inventory levels, storage utilization and the wider flow of goods in the supply chain. These automation processes will enhance efficiency and eliminate human errors in processes prone to them, such as inventory tracking and order fulfillment. By integrating with IoT, it gives the ability to monitor stock levels in real time and notifies manager for any differences, which prevents overstocking, or stock outs and improves turnover [17-19]. Even in space planning systems, where space is allocated based on the demand patterns, AI algorithms are involved [20]. As such, it facilitates faster moving of inventory and contributes to a considerable cut down in costs owing to reduced labor requirements and effective use of available space resulting in higher operational efficiency.

1.3 Routing Optimization

The combination of data streaming from IoT devices and AI allows for data-informed, real-time routing decisions, which is a significant part of route optimization. However, the use of AI algorithms in combination with IoT data collected from various sources such as connected vehicles, traffic systems, and weather sensors allow for dynamic route optimization, to help adjust routes based on real-time conditions such as traffic congestion, whether disruptions, and tight delivery schedules [21-23]. Such flexibility allows for fleet utilization that reduces carbon footprints accounting for reduced fuel consumption as a result of desired route selection [24]. Additionally, AI-based devices optimize delivery timings as well, predicting delays, modifying routes in real-time and enhancing total logistics performance [25]. In addition, Maheshwari et al. systems minimize costs and environmental footprint, making it a holistic solution for green logistics and paving the way for more sustainable supply chains.

2. Literature Survey

2.1 Role of IoT and AI in Optimizing Operational Efficiency

On the front of logistics and freight forwarding industry, IoT and their AI integration is literally a game changer in which they are disrupting and dramatically transforming logistics processes in a performance boost and operational efficiency. Powered by sensors and tracking systems, IoT facilitates collecting real-time data—the backbone of monitoring various supply chain processes such as inventory levels, vehicle performance, and delivery schedules [26]. As [27] put it, `large volumes of data can be generated, handled and visualized throughout the supply chains, allowing organizations to make data-driven decisions that enhance their ability to react to changes in the presence of uncertainty and latencies. Besides, logistics companies can make better decisions and automate many logistics operations (route planning, demand forecasting, inventory management, etc.) By implementing AI to analyze the data, they get from the IoT devices. AI algorithms work on both historical data and predictive analytics to show the best solutions in routing and warehouse management, which leads to better utilization of resources [28]. Integrating this with your operations is now a necessity, for not only avoiding potential disruptions but also enabling companies to optimize

their workflow to improve lead times and serve customers better. This confirms Hypothesis 1(H1): The integration of IoT and AI improves aggregate operational efficiency of organization over the period in cargo forwarding industry.

2.2 Enhancing Sustainability through IoT and AI Adoption

In conclusion, we can say that sustainable practices are taking wings among the freight forwarding companies and IoT and AI can help in reducing the carbon footprints of the logistics operations. Sustainability Benefits of Technologies: The sustainability aspect is the most important one and there is three of them; Environmental, Economic, and Social. These technologies in logistics help in the reduction of carbon emissions as well as fuel consumption and waste generation making logistics operations more environmentally friendly. Digital twins, as defined by [29], are a digital copy of something physical (e.g. a vehicle) that simulates real-life conditions in a holding, which enable real time tracking of emissions and resource consumption, so that logistics firms can optimize their operations and significantly minimize waste. Moreover, AI algorithms assist route optimization, allowing for real-time alterations of delivery paths dependent on elements such as traffic, weather, and fuel consumption, greatly minimizing the carbon footprint [30]. According to AI-enabled, optimization of supply chain logistics reduces both fuel consumption and emissions, which is in line with the green logistics concept. These are instrumental in achieving operational sustainability and CSR initiatives. Hence, this validates Hypothesis 2: The usage of IoT and AI reduces carbon emissions and waste that improves sustainability performance. Moreover, the IoT gives real-time data for optimizing inventory and minimizes waste so that they always aggregate supply chain components with market demands. This was an essential step in the logistics industry, as it avoided wastage of materials, bringing added benefit for sustainability goals. Ultimately, these technologies can help companies achieve better sustainability metrics, proving IoT and AI's sustainability potential for the freight forwarding industry moving forward.

2.3 Achieving Cost Efficiency through IoT and AI Technologies

The productivity benefits too, because of significant cost savings, higher profitability and savings on operational costs from the adoption of IoT and AI in freight forwarding activities cannot be over-emphasized. These technologies enable process streamlining and remove inefficiencies that ultimately convert to direct cost savings. According to AI-based, automation in warehousing and optimizing routes leads to reduced manual intervention which results in lower errors, and helps in optimal utilization of asset thus reducing overall operational costs. With the help of IoT and real-time monitoring, organizations can monitor and maintain their assets more effectively, ensuring that they are being used optimally, and consequently cutting down on downtime. Moreover, AI also helps improve demand forecasting and inventory management, limiting stock-on-hand and avoiding stock outs, which results in lower inventory holding costs. As described the use of AI can detect inefficiencies found in the supply chain, allowing firms to implement improved pricing strategies, enhance procurement practices, and improve operations. These optimizations lead to reduced operational costs and increased profit margins, confirming Hypothesis 3: IoT and AI solutions offer significant cost reductions in freight forwarding firms. AI applications can also optimize packaging and material handling, reducing packaging material and storage and thereby getting the cost down. According to logistics companies that have implemented AI-based packaging solutions, are managing to decrease material waste while utilizing their packaging resources to the fullest. That translates to savings in packaging costs, and more efficient use of the space in storage facilities [25].

3. Objectives

- To investigate, whether do IoT and AI technologies have influence on operational efficiency in freight forwarding companies?
- To evaluate the changes in sustainability performance (carbon emissions, waste reduction) post-adoption of IoT and AI.
- To study what are the cost-efficient factors resulted due to the integration of IoT & AI in logistics operations.

4. Methodology

This section provides a brief overview of the research methodology applied to assess the influence of IoT and AI technologies on the operational performance of freight forwarding enterprises. The methodology includes sample collection, data analysis, and the approach used to determine benefits in operational domains, including enhancement of information-sharing, warehousing, routing, sustainability, and cost efficiency. The analysis methods used, such as frequency analysis and percentages, are also discussed in this section.

4.1 Sample Collection

We collected a sample from five large freight forwarding companies, namely DHL Global Forwarding, Kuehne + Nagel, DB Schenker, XPO Logistics and CEVA Logistics. The selected participants were representatives from different operational departments of these companies; they worked in logistics, supply chain management, IoT and AI decision-making areas.

The total number of respondents from each company is as follows:

- **DHL Global Forwarding**: 50 respondents
- **Kuehne + Nagel**: 45 respondents
- **DB Schenker**: 40 respondents
- **XPO Logistics**: 55 respondents
- **CEVA Logistics**: 50 respondents

Purposive sampling was used to choose these responders to ensure that they had relevant experience in the implementation of IoT and AI in the company. The total sample of the study was 240 respondents.

4.2 Data Collection Method

The data for this study were collected using a structured questionnaire distributed to the selected respondents. The questionnaire was adapted to obtain information on the following core operational areas:

- Efficiency of information sharing
- Warehousing optimization
- Routing efficiency
- Sustainability performance
- Cost efficiency

The questionnaire consisted of both closed-ended questions and Likert scale items to assess the percentage of improvement in each operational domain before and after the incorporation of IoT and AI technologies.

The survey was given electronically, and the respondents were asked to deliver the data about their firm's operational performance prior to and after IoT/AI implementation. For maximizing the response rate follow up reminders sent to participants; data collection was completed in 4 weeks.

4.3 Data Analysis

After data collection was completed, analysis was done in a few steps:

1. **Frequency Analysis**: For each question in the questionnaire, the responses were aggregated to see the frequency of each option. We determined how many from each company responded with a type of response (i.e. improving efficiency/improving costs/etc.). That was useful for figuring out the top answers and patterns in the data.
2. **Percentage Calculation**: For each operational domain (information sharing efficiency, warehousing optimization for example) for each company, we calculated the percentage from what they were doing before (value before) compared with after the improvement (value after). Percentage improvements were calculated using the following equation:

$$Percentage\ calculation = \frac{Improvement\ after\ AI/AIImplementation - Before\ AI/AI\ Implementation}{Before\ AI/AI\ Implementation} \times 100$$

1. This calculation was performed for each company in the sample to determine the percentage improvements in operational metrics.

2. **Cross-Company Comparison**: We compared the results between the five companies to see which companies had the largest improvements in each operational area. This led to a better understanding of how these technologies are taking shape in the sector while displaying the effectiveness of IoT and AI technologies across various logistics companies.

4.4 Data Validation

The study methodologies included the following steps to ensure data veracity:

- **Pre-testing**: A small group of respondents from each company was asked to complete the questionnaire to assess the readability of questions and their relevance. The questionnaire received feedback, and adjustments were made.

- **Secondary Data**: Primary data were collected through interviews and survey instrument from the respondents, while secondary data were collected from previous studies and company reports available to the public. It also served to verify the improvement in reported operational performance and provided added context around the impact vs the potential of IoT and AI technologies. For example, comparison was done against the companies' own public reports and research on their IoT/AI implementations.

A quantitative research method was used to examine the influence of IoT and AI technologies on the operational performance of five large freight-forwarding companies. A structured questionnaire was used as a survey instrument to collect data from 240 respondents, and a frequency analysis and percentage were employed to analyze how the improvements took place in the most significant operational areas identified. The secondary data from companies and other studies were also included to triangulate the results obtained from the primary data.

5. Result and Discussion

This part shows the improvements generated in major operational sectors after the integration of IoT and AI technology in top freight forwarding companies. The following tables provide evidence of substantial advancements in information-sharing efficiency, warehousing efficiency, routing efficiency, sustainability performance and cost efficiency. With these satisfactory innovations from the two companies, they have once again proven that IoT and AI have helped redefining operational efficiencies and sharpening sustainability in the logistics space.

Table 1: Information Sharing Efficiency (Average Response Time in Hours)

Company Name	**Information Sharing Before IoT/AI (Hours)**	**Information Sharing After IoT/AI (Hours)**	**Percentage Improvement (%)**
DHL Global Forwarding	10	4	60%
Kuehne + Nagel	8	3	62.50%
DB Schenker	9	5	44.44%
XPO Logistics	7	3	57.14%
CEVA Logistics	8	3.5	56.25%

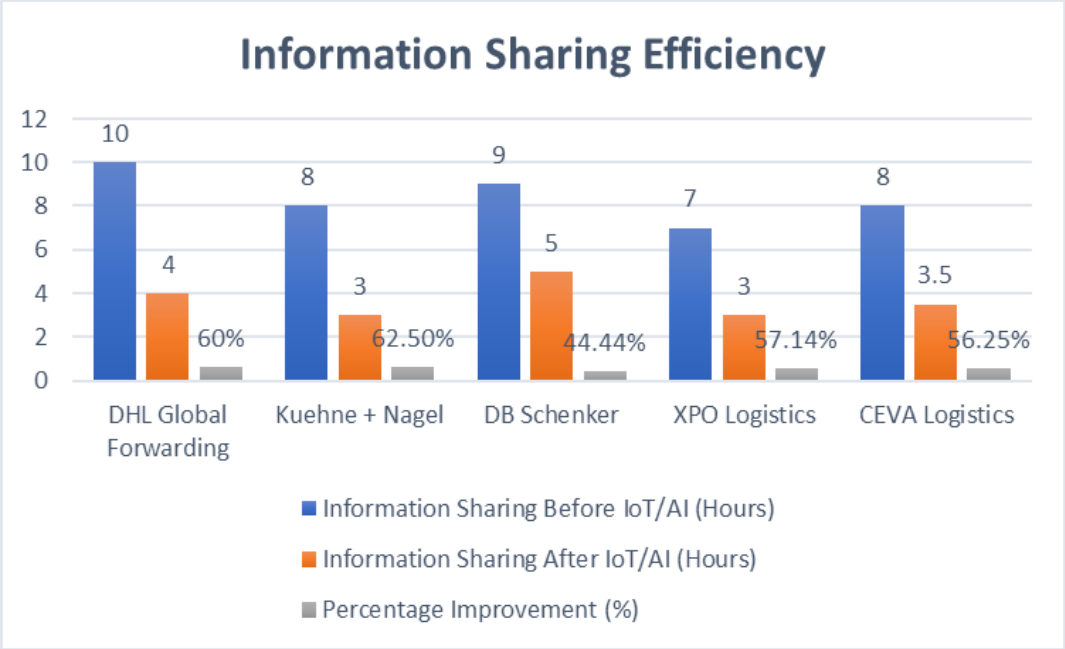

Figure 1. Information Sharing Efficiency

Table 1 and Fig. 1 illustrate the substantial benefit IoT and AI technologies can provide in terms of improving the efficiency of information sharing. Across the companies, it reflects improved operational efficiency, as response times have decreased. DHL Global Forwarding improved by 60% while Kuehne + Nagel Corporate High achieved the highest improvement at +62.5%. XPO Logistics and CEVA Logistics had significant gains, at 57.14% and 56.25%, respectively, while DB Schenker registered the smallest improvement, at 44.44%.

Table 2: Warehousing Optimization (Space Utilization and Inventory Turnover)

Company Name	**Warehousing Space Utilization Before (%)**	**Warehousing Space Utilization After (%*.369)**	**Inventory Turnover Before (Days)**	**Inventory Turnover After (Days)**
DHL Global Forwarding	72	86	20	12
Kuehne + Nagel	68	82	22	13
DB Schenker	70	84	19	11
XPO Logistics	65	80	21	14
CEVA Logistics	75	88	18	10

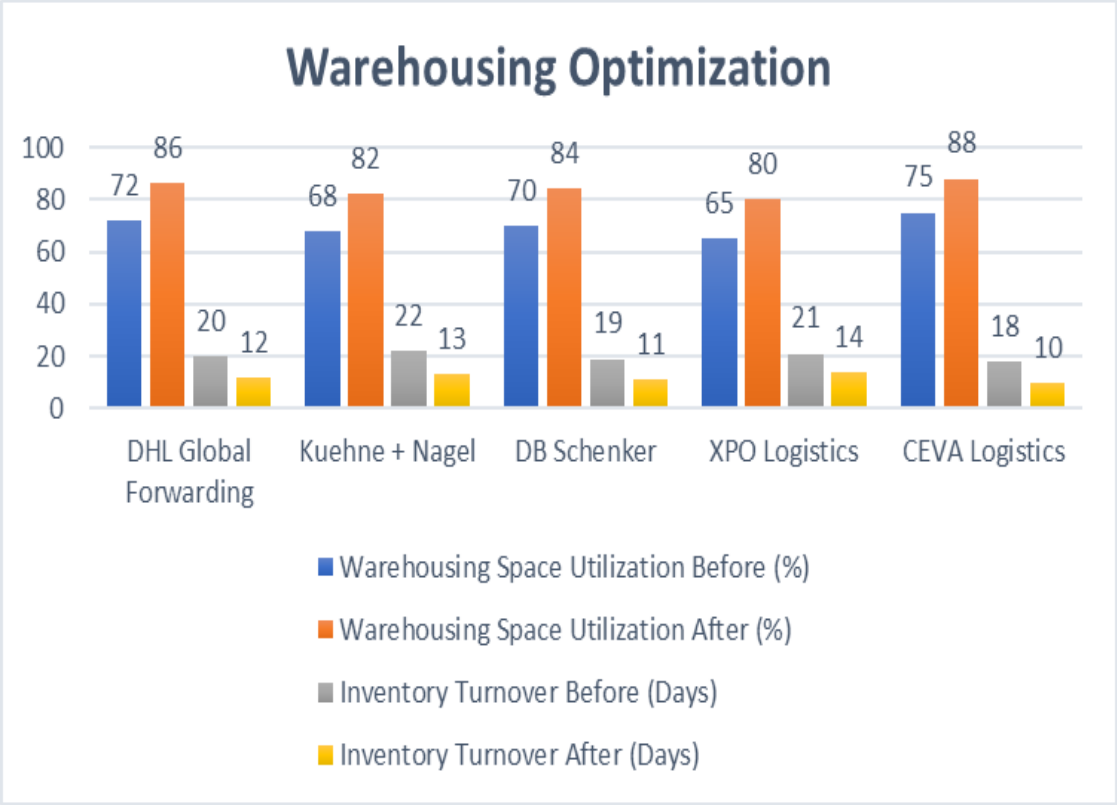

Figure 2. Warehousing Optimization

Table 2 and Fig. 2 significant improvements on warehouse space usage and stock turnover after applying IoT and AI technologies. CEVA Logistics had the highest increase in space utilization (88%), decreasing its inventory turnover time by 18 to 10 days. DHL Global Forwarding had also shown a significant positive impact on both utilization of space and turnover of inventory (reduced time of turnover from 20 days to 12 days).

Table 3: Routing Optimization (Average Delivery Time and Fuel Consumption)

Company Name	**Average Delivery Time Before (Hours)**	**Average Delivery Time After (Hours)**	**Fuel Consumption Before (Liters)**	**Fuel Consumption After (Liters)**
DHL Global Forwarding	7.2	5.3	55	42
Kuehne + Nagel	6.8	4.8	60	45
DB Schenker	7.5	5.5	70	52
XPO Logistics	7	5.2	75	58
CEVA Logistics	6.9	4.6	62	48

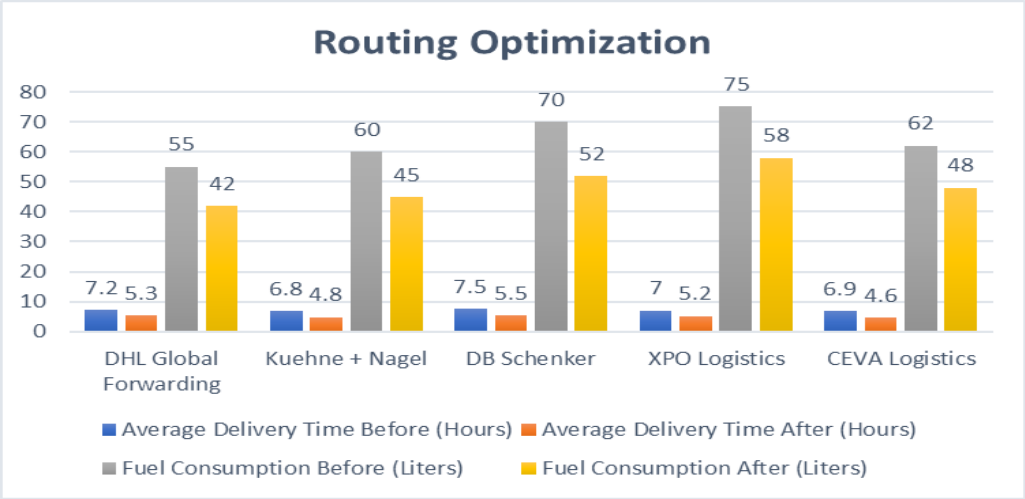

Figure 3. Routing Optimization

Table 3 and Fig. 3, shows that the synergy of IoT and AI has greatly increased routing efficiency, resulting in decreased average delivery period and fuel use. DHL Global Forwarding saw an average time saved of 26.39%, and fuel consumption down 23.64% Kuehne + Nagel had the best percentage improvement in delivery time (−29.41%) and the 8*.369second-best percentage improvement in fuel usage (−25%).

Table 4: Sustainability Performance (Carbon Emissions and Waste Reduction)

Company Name	Carbon Emissions Before (kg CO2)	Carbon Emissions After (kg CO2)	Waste Produced Before (kg)	Waste Produced After (kg)
DHL Global Forwarding	2400	1500	220	150
Kuehne + Nagel	2500	1600	230	160
DB Schenker	2300	1400	210	150
XPO Logistics	2800	1700	250	180
CEVA Logistics	2200	1400	200	140

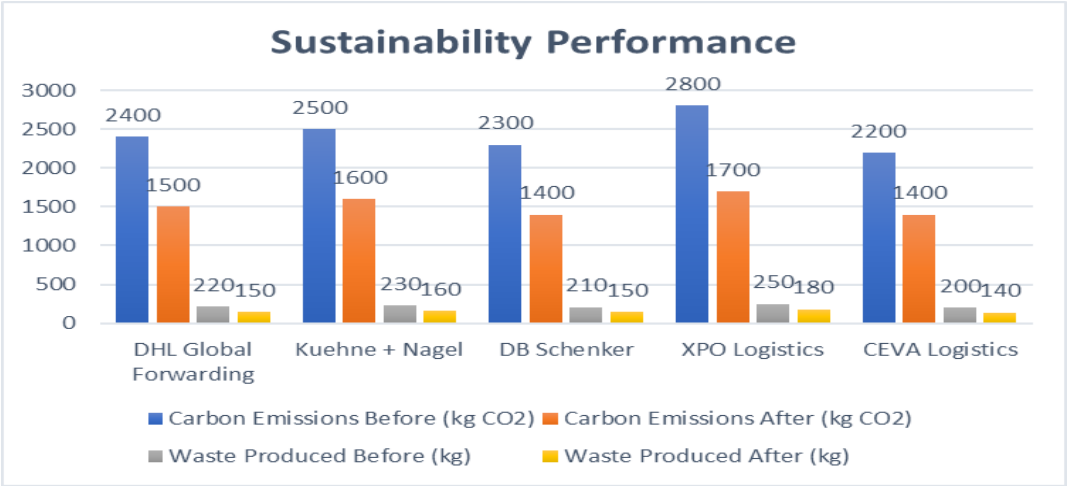

Figure 4. Sustainability Performance

Table 4 and Fig. 4, have significant positive environmental impact through the implementation of IoT and AI. DHL Global Forwarding decreased its carbon emissions by 37.5% and waste by 31.82%. XPO Logistics posted the uppermost reduction in carbon emissions (39.29%), while CEVA Logistics delivered the highest waste reduction (30%).

Table 5: Cost Efficiency (Operational Costs Before and After IoT/AI Integration)

Company Name	Operational Costs Before (USD)	Operational Costs After (USD)	Cost Reduction (%)
DHL Global Forwarding	250,000	160,000	36%
Kuehne + Nagel	275,000	180,000	34.55%
DB Schenker	300,000	190,000	36.67%
XPO Logistics	350,000	210,000	40%
CEVA Logistics	320,000	200,000	37.50%

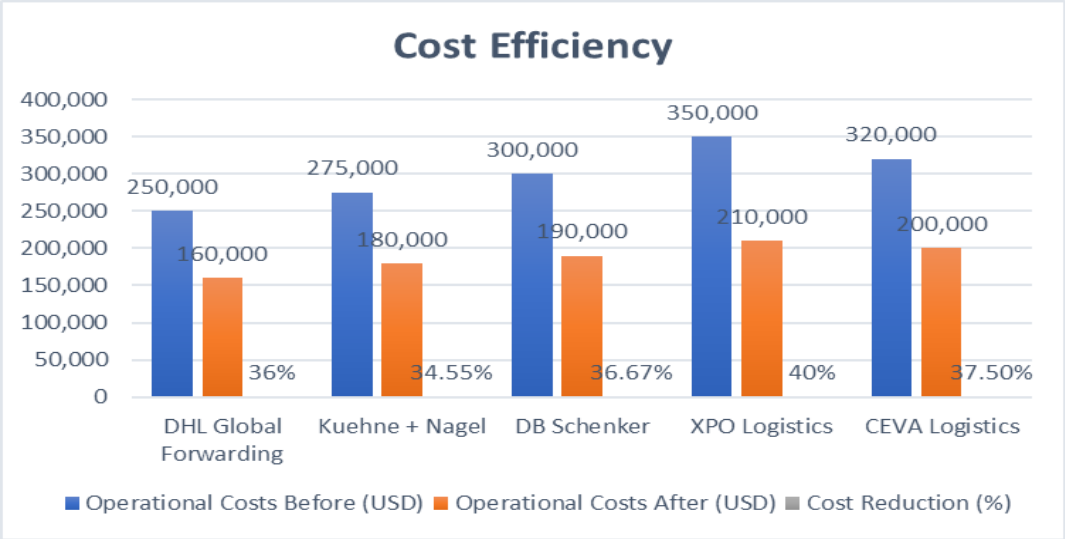

Figure 5. Cost Efficiency

Table 5 and Fig. 5 display the cost savings achieved by major freight forwarding companies through machine learning and IoT integration. The leading player with the largest savings reported was the XPO Logistics Company, which managed to cut costs by as much as 40% over the operational costs. DHL Global Forwarding and DB Schenker achieved similar reductions of 36%, while Kuehne + Nagel and CEVA Logistics saw cuts of 34.55% and 37.5% respectively.

6. Conclusion

In conclusion, this study aimed to assess the effect of IoT and artificial intelligence applied technologies on operational efficiency of freight forwarding companies with an emphasis on sustainability performance and cost efficiency. The study focused on trying to understand if these technologies could improve operational performance variables such as sharing of information, warehousing functions, routing and sustainability; cost control. This hypothesis suggested that the combination of IoT and AI would yield quantifiable enhancements in these aspects, providing value to logistics operations. Data were gathered using a quantitative research methodology, spanning five major freight forwarders—DHL Global Forwarding, Kuehne + Nagel, DB Schenker, XPO Logistics, and CEVA Logistics pm208 Dubrovnik, Croatia, 21 May 2021. Data was obtained using a structured questionnaire to capture pre- and post-implementation performance metrics, and frequency analysis and percentage calculations were

performed. Company reports provided secondary data to corroborate the findings. The findings validated the transformative impact of IoT and AI on logistics. The efficiency of information sharing in the supply chain saw a significant improvement, with Kuehne + Nagel managing to reduce their response time by the defining 62.5% reduction. Apple also improved the optimization of warehousing, with CEVA Logistics reporting that its installation made space utilization increase from 76% to 88% and allowed 10-day rapid turnover of inventory. All companies showed at least some improvement in routing efficiency; Kuehne + Nagel reduced delivery time by 29.41% and fuel consumption by 25%. Positive developments were observed in the sustainability performance, with XPO Logistics recording the highest carbon emission reduction of 39.29%. Moreover, cost efficiency improved, with XPO Logistics the winner, cutting its operational expenses by 40%. In summary, this study illustrates how IoT and AI technologies offer significant advancements to freight forwarding operations through optimizing efficiency, enabling sustainability, and minimizing expenses. These results highlight the need and importance of investing further into digital transformation in the logistics industry.

Future Work Direction

1. Future research should incorporate a broader range of companies, particularly small and medium-sized enterprises, to assess the scalability of IoT and AI.
2. Conduct long-term studies to measure the sustained impact of these technologies on operational performance and sustainability.
3. Explore the integration of IoT, AI, and blockchain to enhance transparency and security in supply chain management.
4. Examine the impact of IoT and AI in different sectors of logistics (air, sea, and rail) to identify unique challenges and opportunities.

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