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Implementation of Lean Six Sigma to Improve Logistic Operational Performance in the Industrial Boiler Manufacturing

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Abstract in English

Logistic operational is the heart of supply chain management that must always exist simultaneously to maintain the sustainability of a business operation in an era of high competitiveness by continuing to provide positive impacts on people and the planet. This is what prompted the Author to conduct a case study on a multinational company that produces industrial boilers and their equipment. The Lean Six Sigma methodology used has proven effective in finding the root of the problem, measuring achievements, analyzing data, preparing improvement steps and controlling each improvement process to ensure continuous improvement. Through joint efforts in the Focus Group Discussion forum, this study has proven to have helped the company to improve its previous condition, where logistics operational costs were very high due to the high cost of the inward process and had an impact on the high carbon footprint produced by transportation equipment, especially those related to the outward process. Improvement in logistics operational performance in the inward and outward processes that resulted cost saving in six months of implementing the improvements. This achievement not only provides financial benefits for the organization, but also impacting to minimize carbon footprint.

INTRODUCTION

Businesses across a range of industries must consider sustainability in their operations in the age of globalisation and escalating corporate competition. Businesses that wish to stay profitable and relevant over the long run now prioritise business sustainability. Given the boiler manufacturing industry's experience, logistics transportation management is critical in determining the company's overall operational sustainability. As a component of operational management, logistic transportation management needs to be closely watched and enhanced through the apprisal process. Logistics costs include expenses incurred in the inward and outward processes. The inward process refers to every supply chain activity sourced from outside to the factory area. Sources can come from both domestic and international origins, and the outward process involves every supply chain activity originating from the factory area and/or subcontractors to the warehouse or customer area. Both processes are the focus of this research. This research was done at PT. XYZ, one of the Industrial Boiler manufacturers at Indonesia.

In the lesson learn process, the organization, PT. XYZ, identifies problems by focusing on Key Performance Indicators (KPIs) that have not met the expected targets or have significant gaps. One of the indicators that shows a significant gap during the fiscal year (FY) period from

April 2022 (FY22-23) to March 2024 (FY23-24) is the overrun of logistics costs. Figure 1 shows the logistics cost performance versus quarterly revenue achievement.

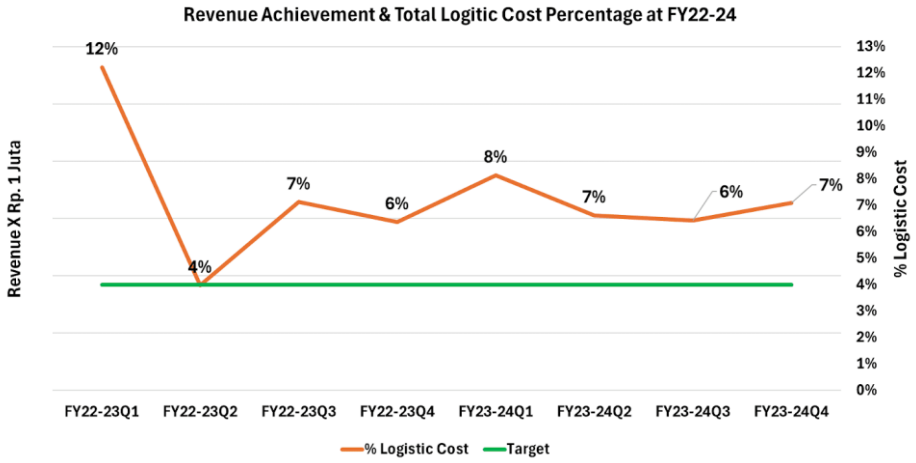

Figure 1. Logistics Cost Performance (Before improvement)
Source : PT. XYZ monitoring data (2024)

The purpose of the research on the logistics process at PT. XYZ is as follows:

1. Determining the root causes of logistics cost overruns during the FY22-24 fiscal year period and corrective measures to address them.
2. Determining the ratio of sales revenue to the potential increase in carbon footprint during the FY22-24 period.
3. Measuring the results of the implemented improvement steps on the reduction of logistics cost overruns and the increase in the ratio of carbon footprint revenue to carbon footprint reduction.

Empirical studies on problem-solving in the context of logistics cost overruns involve a systematic investigation of the factors contributing to those cost overruns and testing solutions in real-world scenarios. In this paper, the authors chose the Lean Six Sigma methodology, which consists of five stages: definition, measurement, analysis, improvement, and control.

Prior studies on the optimisation of logistics operations in the industrial sector were carried out by Maryadi (2021), which the author was able to locate. The purpose of the logistics process and the setting in which the research was carried out are where the author's study and Maryadi's (2021) research diverge. While this study examines waste in PT. XYZ's outbound logistics operations, Maryadi examined NVA (Non-Value Added) in the internal supply chain operations of an automobile manufacturing company in Cikarang, West Java.

Research on logistics cost overruns requires the identification of variables related to logistics costs. The derivation of constructed research variables is translated as an operational definition that provides the boundaries or meaning of a variable by detailing what the researcher must do to measure that variable, or it can be succinctly interpreted that the variables in this research are limited in their operational meaning. The variables operationalized in this study include sales results, shipping costs, and carbon emissions or carbon footprint.

LITERATURE REVIEW

Supply chain management within corporate organizations creates and delivers goods to end users, therefore it is necessary to find the best approach to design a fast process at a low cost, as well as timing and location that meet the needs of the end users. The year 2013 saw Chopra and Meindl. In sustainable supply chain management, also known as Sustainable Supply Chain Management (SSCM), environmentally friendly logistics and operations are crucial because they reduce waste, have a positive impact on the environment, and enhance profitability. According to Teixeira (2018). Companies often manage their logistics operations to focus on their core competencies and reduce fixed costs.

The effective concept of implementing sustainable development in logistics and supply chain management is based on the use of management decision-making methods to alter the parameters of logistics flow. Decisions must be made based on the measurement and evaluation of the parameters and indicators of that flow (Osintsev, 2020). According to (Chopra, 2017), the design of the transportation network affects supply chain performance by building the infrastructure where transportation operational decisions related to scheduling and routing are made. A well-designed transportation network allows the supply chain to achieve the desired level of responsiveness at a low cost. This is the basis for writing this paper, which determines the state of the art in its writing. The State-of-the-Art of this paper focuses on the analysis of waste occurring in the inward and outward logistics activities at PT. XYZ, which is an organization engaged in the manufacturing of industrial boilers.

According to Klimecka (2021), the implementation of environmentally friendly transportation strategies, including the use of eco-friendly vehicles, is a key aspect of sustainable development in the logistics sector. Strategic logistics management is a crucial part of today's business world, especially in the context of international activities.

The authors developed a framework that depicts the phases of the study while doing this research. The framework for this study, referred to as the conceptual framework, is depicted in Figure 2.

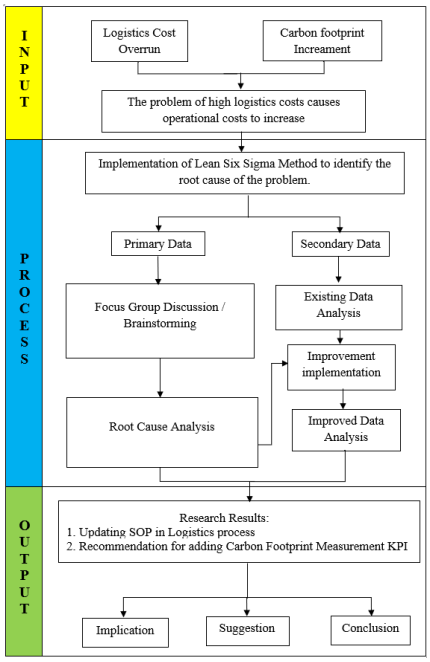

Figure 2. Framework of Research
Source : Author (2024)

RESEARCH METHOD

This research uses a descriptive quantitative type or model. According to (Priadana & Sunarsi, 2021), quantitative research is conducted using investigative methods on phenomena through data collection that can be mathematically operated using statistical and computational techniques. Meanwhile, descriptive research is used to describe or illustrate the results of quantitative research. Descriptive research uses the 5W + 1H method to describe the research subjects. In the quantitative descriptive research model, the data obtained consists of numbers related to the frequency and shipping costs in each logistics process that occurs at PT. XYZ. The sources of data collected by the Author are derived from the following data:

a. Primary Data

Data obtained directly from original sources or through direct observation by researchers in the field, sourced from information provided by stakeholders related to our research object, obtained through Focus Group Discussions (FGD) or brainstorming.

b. Secondary Data

The secondary data used in this study comes from recorded data or quality records from the research object in the period before the research or repair time, namely in the fiscal year period 2022 to 2023. The research object in question is the logistics process related to two types of commodities, namely finished products, namely boilers (products) and spare parts (spare). The types of secondary data used in this study are as follows:

1. Budget (Original budget)
2. Logistics Operational Documents
3. Distance

The data analysis method used in this research follows the DMAIC stages, which are phases in the Lean Six Sigma methodology. Lean Six Sigma has proven to support sustainability in supply chain management in various ways. This helps in the development of processes with less waste and variability, which is crucial for sustainable operations (Barbosa, 2023).

Define Phase

In this phase, the analysis begins with reviewing the Inward and Outward process flows according to the actual conditions during the research period. After the process flow is illustrated, the analysis is conducted by identifying parts of the process that show phenomena or determining indications of "waste".

From the initial interview with the logistics team, several obstacles faced by the team in both the Inward and Outward processes were identified, namely:

1. In the Inward process:
    - The high cost of DO LCL
    - The high level of communication conducted with the forwarder agent
2. In the Outward process:
    - The high shipping costs from the subcontractor's factory to the customer
    - The material or spare parts were damaged when received by the customer

The next step in this research is to prepare the Project Charter. The members of this FGD consist of representatives from several departments at PT. XYZ, namely: Procurement, Logistics, and OEG. This project itself is facilitated by the Author and fully supported by subject matter experts (SMEs) and the top management of PT. XYZ, who are also the sponsors of this project. Figure 3 below shows the Project Charter that was jointly prepared by the FGD team.

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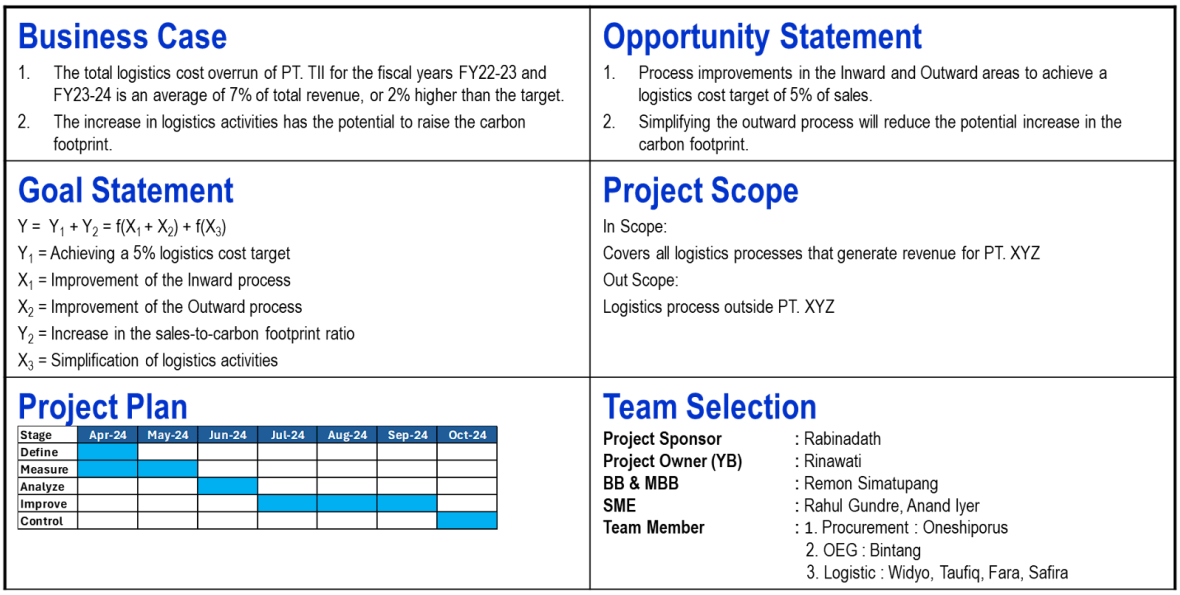

Figure 3. Project Charter
Source : FGD (2024)

Measurement Phase

In the Measure phase, historical data, specifically logistics data from 2022 to 2024, is processed using Ms. Excel™ to determine the trends and also to evaluate the current process conditions. Every factual finding in the Measure phase is crucial for identifying areas that need improvement and for validating each potential cause of the problem. In this research, the Author processes secondary data to obtain related information:

1. The contribution of sales from each type of product compared to the logistics costs incurred
2. Comparison of actual inward and outward logistics costs
3. Comparison of budget and actual logistics costs
4. Comparison of IncotermsTM logistics costs
5. Measurement of Land Transportation Mode Frequency and Costs onward
6. Measurement of Additional Outward Costs
7. Measurement of Total Distance Traveled and Fuel Consumption
8. Measurement and Calculation of Carbon Footprint

***Analyze* Phase**

In this phase, FGD members conduct discussions to determine the potential causes of each issue from the three main problems.

1. Analysis and validation of the Causes of High Inward FCL Costs (Figure 4 & Table 1)

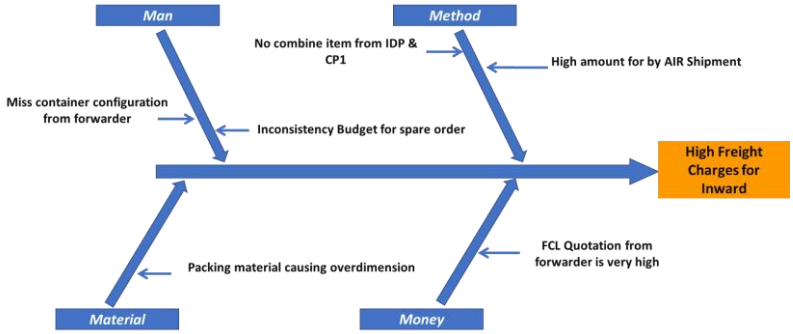

Figure 4. Fish bond diagram of High FCL Costs
Source : FGD (2024)

Table 1. Critical X's Validation of High FCL Costs

No	Critical X's Validation	Evidence	Category	Conlusion
1	The forwarder incorrectly determines the container's load capacity requirements	Information on capacity requirements comes from PT. TII. If PT. TII provides incorrect information which results in errors in choosing transport capacity	*Man*	No valid
2	The logistics budget for spares products is not consistently entered into Oracle ERP	The consistency of data entry into ERP is of no direct relevance to the high costs of Inward FCL.	*Man*	No valid
3	The same Material Items for CP1 and IDP are purchased and dispatched separately	Separate purchases and departures will increase logistics costs	*Method*	Valid
4	Tingginya pengiriman produk Spares dengan moda udara	High delivery of Spares products by air	*Method*	Valid
5	Non-standard material packaging causes over dimensions and cannot be loaded with other materials in one container	The number of reports related to goods not being able to be loaded only occurred less than 5 times in two fiscal year periods	*Material*	No valid
6	Penawaran biaya FCL dari *contract forwarder* agent sangat tinggi	The FCL fee offer from the contract forwarder agent is very high	*Money*	Valid

Source : FGD (2024)

2. Analysis and validation of the Causes of High Outward Costs
3. Analysis ad validation of the Causes of the Low Sales Ratio to Carbon Footprint

Before the research continues, each idea is grouped based on the "X group," where each valid potential cause of the problem will later become the "X function" needed for identification to facilitate the Author in analyzing the cause of the problem until the determination of the corrective steps later. Table 2 shows the selection process for prioritizing potential causes of the problem.

Table 2. Critical X's Priority Selection Table

NO	X Group	Critical X's Validation	Impact of Improvements			Level of convenience			Processing Time	Total skor	Ranking
			Financial gain (9:High)	Int/Ext customer satisfaction (9:High)	Chance of increased efficiency (9: High)	Chance of success (9:High)	Easy to run (9:Easy)	Execution costs (9: Cheap)			
1	X_1	The same Material Items for CP1 and IDP are purchased and dispatched separately	9	9	9	9	3	3	3	45	7
2	X_1	High delivery of Spares products by air	9	9	9	3	3	3	3	39	9
3	X_1	The FCL fee offer from the contract forwarder agent is very high	9	9	9	9	9	9	9	63	1
4	X_2	The distance traveled from the fabrication area to the customer area is very long	9	9	9	9	3	9	3	51	4
5	X_2	Information regarding the results of travel surveys to customer sites is not yet available	9	9	3	9	3	3	9	45	6
6	X_2	Offers high outward costs	9	9	9	3	3	9	3	45	5
7	X_3	The frequency of product and SFG shipments outside Jabodetabek is very high	9	9	9	3	9	9	9	57	3
8	X_3	There is no method for measuring carbon footprints	9	9	9	9	9	9	9	63	2
9	X_3	Dependence on High-Emission Modes of Transportation	9	9	9	3	3	3	3	39	8
Note : 9 ➔ Fulfill criteria, 3 ➔ May fulfill criteria, 1 ➔ Not fulfill criteria											

Source : FGD (2024)

Improve Phase

After the problems are arranged from highest to lowest score based on the priority selection results table in a Gantt Chart as shown as Table 3, the next step is to determine the root cause using the 5 Whys Analysis method. It is shown as Table 4. The FGD team selected the 5 top rank to be determined its root cause.

Table 3. Critical X's Gantt Chart

RANK	X Grou	CRITICAL X'S VALIDATION	CATEGORY	PIC	Apr-24		May-24				Jun-24				Jul-24				Aug-24				Sep-24				Oct-24			
					V3	V4	V1	V2	V3	V4	V1	V2	V3	V4	V1	V2	V3	V4	V1	V2	V3	V4	V1	V2	V3	V4	V1	V2	V3	V4
1	X1	The FCL fee offer from the contract forwarder agent is very high	*Money*	Rina																										
2	X3	There is no method for measuring carbon footprints	*Method*	Remon																										
3	X3	The frequency of product and SFG shipments outside Jabodetabek is very high	*Method*	Bintang																										
4	X2	Offers high outward costs	*Money*	Widyo																										
5	X2	Information regarding the results of travel surveys to customer sites is not yet available	*Method*	Fara																										

Keterangan warna : = M - A = I = C

Source : FGD (2024)

Table 4. 5 Whys Analysis of Issue Rank No.1

Issue	Why #1	Why #2	Why #3	Why #4	Why #5
The FCL fee offer from the contract forwarder agent is very high	The FCL fee offered by the forwarder agent in the contract refers to the highest market price when the contract was made in the 4th quarter of fiscal year 2022	Price reviews in the contract are carried out every 6 (six) months, while market price fluctuations are quite high and can change every month.	Lack of information possessed by staff in the logistics department regarding fluctuations in FCL costs in the market	Staff in the logistics department only refer to the prices stated in the contract without looking for price comparisons from other forwarders	There has not been an article in the contract that states that costs can be reviewed if there are significant changes in market prices

Source : FGD (2024)

From Table 4, it is known that the root cause of the problem regarding the high FCL cost offer from the contract forwarder agent is "the absence of a clause in the contract stating that costs can be reviewed if there is a significant change in market prices." The content of the final "Why" was then included in the Improvement Plan Table under the "Why" column. Next, the FGD team formulates the answers and creates a corrective action plan using the format shown in Table 5 below.

Table 5. Table of Improvement Plan rank no.1

NO	WHAT	WHY	HOW	WHAT IF PROBLEM	COUNTER MEASURE	WHO	WHERE	WHEN	HOW MUCH
1	The FCL fee offer from the contract forwarder agent is very high	There has not been an article in the contract that states that costs can be reviewed if there are significant changes in market prices	1. Drafting amendments to change contract reviews from every 6 months to every 2 months 2. Added article regarding FCL costs not being bound by contract 3. Logistics staff looks for the cheapest offers	Contract agent forwarder refuses changes to FCL costs	1. Postpone the extension of the work contract which ends in early April 2024. 2. Stop the contract extension if after discussion the forwarder agent is still unwilling to accept amendments regarding FCL fees	Rina; Remon	PT. TII, Plant Cilegon	April 2024	N/A

Source : FGD (2024)

The summary of the improvement plan of every rank can be seen in Table 6 below.

Table 6. Table of Summary of Steps to Address Logistics Cost Overrun

No	Problem	Root Cause	Improvement Plan
1	The FCL cost offer from the contract forwarder agent is very high during the inward process.	The absence of a clause in the contract stating that costs can be reviewed if there is a significant change in market prices.	1) Drafting an amendment to change the contract review from every 6 months to every 2 months 2) Adding a clause regarding FCL costs not bound by contract 3) The logistics staff are looking for the cheapest offer.
2	The frequency of product and SFG shipments outside Jabodetabek is very high during the outward process.	Collaboration with fabrication subcontractors located near ongoing projects or customer areas is still very limited in number.	1) Asking the SCM team to gather information and visit several fabrication subcontractors 2) Entering work contracts with several fabrication subcontractors located outside Jabodetabek.
3	The distance traveled from the fabrication area to the customer area is very far during the outward process.	The supplier delivers products from their factory using an agent of their own choosing and then unloads them at the dock to be loaded into containers.	1) Asking the agent to arrange the centralization of importing goods delivery directly from the factory area by eliminating the loading process. 2) Sending the container directly to the customer's area
4	High outward cost offers in the outward process	There is no collaboration yet with other domestic forwarder agents that have a wider network and transportation modes that meet the needs.	1) Inviting several new forwarder agents to discuss network availability and modes of transportation. 2) Preparing a work contract with the selected forwarder agent
5	The information regarding the survey results of the trip to the customer site during the outward process is not yet available.	Mitigation needs to be carried out early to ensure transportation modes can pass through the route, as well as additional lifting and handling equipment support if necessary.	1) Conducting assessments/visits to ensure the availability of suitable transportation modes 2) Adding the Travel Survey process into the standard operating procedures in the logistics department

Source : FGD (2024)

The carbon footprint generated during the FY22-24 period amounts to 328,466 KgCO2, as shown in the total sum in Table 7 below.

Table 7. Carbon Footprint Measurement and Calculation Table FY22-24

Moda	Frekuensi	Total Biaya Outward (X Rp.1 juta)	Total Jarak (Km)	Fuel Consumption (Km/L)	Total Konsumsi BBM (L)	Emision factor (Kg/L)	Emisi CO2 (Kg)	Rasio Emisi CO2 (Kg)
CDD	77	331	32.202	12	2.683	2,9249	7.849	2%
FUSO	102	535	30.480	5	6.096	2,9249	17.830	5%
LOWBED	53	1.481	29.126	1	58.251	2,9249	170.379	52%
TRAILER	57	564	19.023	1	19.023	2,9249	55.640	17%
TRONTON	110	841	41.732	3	13.911	2,9249	40.687	12%
CDE	26	61	7.389	3	2.463	2,9249	7.204	2%
L300	67	135	16.835	3	5.612	2,9249	16.414	5%
LCL	4	22	4.261	1	4.261	2,9249	12.463	4%
TOTAL		3.969	181.047		112.300		328.466	100%

Source : FGD Data (2024)

Control Phase

In this phase, the FGD team continues the discussion to determine preventive and control measures in the implementation of improvements. The actions taken in this phase are as follows:

1. Updating the Standard Operating Procedure (SOP) documents related to several activities mentioned above, including:
    a. Prosedur Proses Impor CP1 & IDP
    b. Outward Material Procedure
    c. Procedimiento de Estándares de Seguridad para Transportistas
    d. Material Procurement Procedure
2. Creating a form template as a reference for submitting price quotes

To facilitate the logistics staff in requesting price quotes from forwarder agents, the FGD team formulated a template form to calculate the estimated costs that will be incurred. The form, in the form of a worksheet using the Microsoft ExcelTM application, will greatly assist the logistics staff in determining the standard cost of a shipment.

RESULTS AND DISCUSSION

After the corrective measures have been implemented for approximately 2 quarters, the results of the improvements can be seen in Figure 5 below.

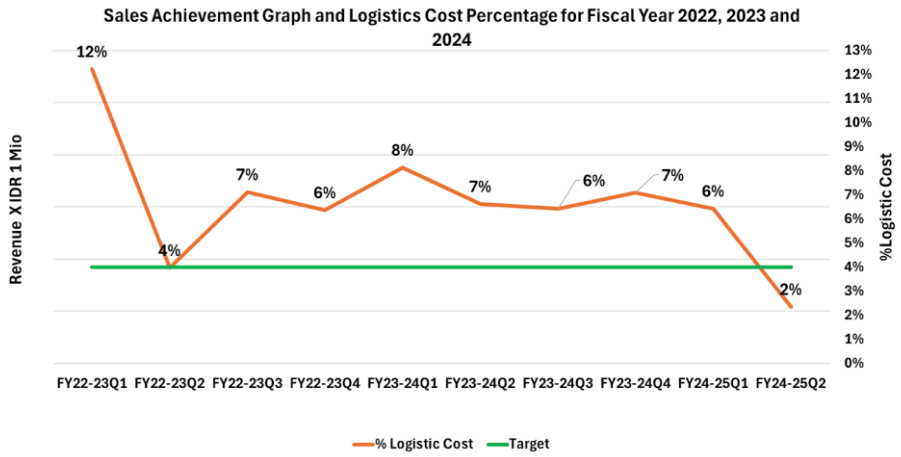

Figure 5. Logistics Cost Performance (After Improvement)
Source : PT. XYZ monitoring data (2024)

The image above shows a drastic decrease in costs at the end of the second quarter of the fiscal year 2024 to 2%. This achievement is below the logistics cost target of 4% of the revenue value. In the first quarter of FY24-25, the decline has not occurred optimally because several improvement projects will only be effective starting in June 2024.

As stated in Table 7 regarding the relationship between fuel consumption and carbon footprint value, where the higher the fuel consumption, the greater the carbon footprint value produced. Conversely, if fuel consumption decreases, the carbon footprint value will also decrease. With the decrease in fuel consumption in the first quarter of the 2024 fiscal year, the carbon value also decreases. Table 8 shows the measurement results and calculations of the Carbon Footprint value for FY24-25H1 for selected modes of transportation.

Table 8. Table of Measurement and Calculation of Carbon Footprint FY24-25H1

Moda	Frekuensi	Total Biaya Outward (X Rp.1 juta)	Total Jarak (Km)	Fuel Consumption (Km/L)	Total Konsumsi BBM (L)	Emision factor (Kg/L)	Emisi CO2 (Kg)	Rasio Emisi CO2 (Kg)
CDD	6	27	4624	12,00	385	2,9249	1127	2%
FUSO	18	190	13264	5,00	2653	2,9249	7759	17%
LOWBED	8	112	3328	0,50	6656	2,9249	19468	43%
TRAILER	24	166	3239	1,00	3239	2,9249	9474	21%
TRONTON	8	243	7488	3,00	2496	2,9249	7301	16%
TOTAL	64	738	31943		15429		45129	100%

Source : FGD Data (2024)

After the carbon footprint value is calculated, the next step is to calculate the sales-to-carbon footprint reduction ratio. The results of the calculation can be seen in Figure 6 below.

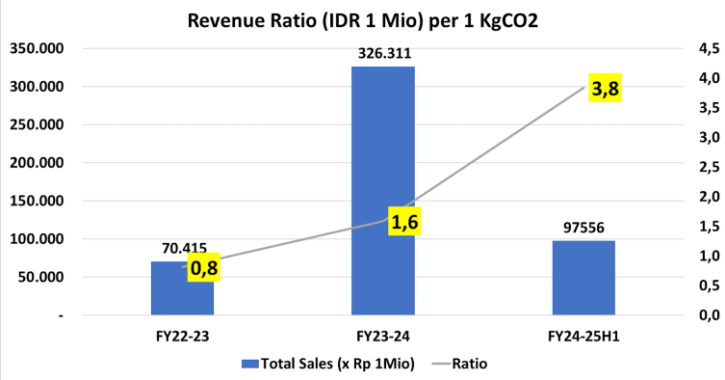

Figure 6. Sales Ratio per 1KgCO2 FY24-25H1 (After Improvement)

Source : FGD Data (2024)

CONCLUSION

From the graph above, it is known that the achievement of the sales ratio per 1 Kg of CO2 emissions has increased significantly, from 1.6 in the fiscal year FY23-24 to 3.8 in the fiscal year FY24-25, or if expressed as a percentage, the increase is 237%. That achievement serves as evidence that there has been an improvement in the operational performance of green transportation management. And this result answers the questions posed in the Problem Formulation.

1. Based on the facts found in the measurement results and analysis conducted by the FGD team, it is known that the logistics cost overrun is caused by several factors:
2. The FCL cost offer from the contract forwarder agent is very high during the inward process.
3. The frequency of product and SFG shipments outside Jabodetabek is very high during the outward process.
4. The distance traveled from the fabrication area to the customer area is very far during the outward process.
5. High outward cost offers in the outward process
6. The information related to the survey results of the trip to the customer site during the outward process is not yet available.

Of the five issues mentioned above, 4 out of 5 issues originate from the outward process. This indicates that the outward process dominates the logistics cost overrun issues occurring at PT. XYZ during the fiscal year 2022 to 2023.

This implication of ths project is divided into two main parts, namely tangible and intangible implications. Tangible implications are impacts that can be calculated and generally use discrete data. Meanwhile, intangible implications use qualitative continuous data that can be measured through quantification.

According to this paper, we can learn that by applying a methodology that uses data, problem-solving tools, and a directed thinking process, the improvement steps will be more targeted and effectively solve the problem. Especially for green transportation, the future research can put the attention to improve current fossil fuel transportation to be renewable fuel transport, such as electric vehicles.

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