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Designing Factory Layout and Facilities for Car Front Door Production with CORELAP: A Case Study at PT GMI

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Abstract

The automotive manufacturing industry is experiencing significant development and has increasingly complex market demand dynamics. The industrial transformation resulting from these developments has had a significant impact on several automotive manufacturing companies. The value of production efficiency, on-time delivery, and product quality means that companies must have the right strategy in meeting customer demand. Fulfilling customer requests can be realized by opening new adequate facilities. Factory layout and facility design can be a key factor in achieving this goal, especially in the production of front door components model. This research aims to comprehensively detail the design of the factory layout and facilities using the CORELAP method. CORELAP implementation involves collecting supporting data, including Operation Process Chart (OPC), Routing Sheet, Floor Area Requirement, Activity Relationship Chart (ARC), and Activity Relationship Diagram (ARD). The CORELAP method prioritizes spatial relationships to ensure that closely related facilities are strategically located. Design This layout design was created to provide an overview of the strategy for structuring production facilities and their supports to produce an effective and efficient design. Apart from the overview, the analysis carried out can also provide space for stakeholders to be able to utilize the CORELAP strategy in creating new factory layouts and facilities to support improving the company's work performance and meet customer satisfaction. The cost of material handling is calculated to determine the expenses involved in establishing a production facility for car front doors, totaling IDR 763,959. This cost is approximately 10% lower than the current material handling cost, which is IDR 856,888. The results of this research are design proposals that can be utilized or taken into consideration by industrial stakeholders.

***Keywords**: Automotive Manufacture, CORELAP, Design, Door Production, Factory Layout*

1. Introduction

The automotive industry has experienced substantial growth worldwide over the past few decades, evolving from a a niche market to a major driver of the global economy. This growth has been driven by advancements in technology, shifting consumer preferences, and increasing economic development in various regions. The layout of the automotive industry plays a pivotal role in ensuring efficient and streamlined production processes. As the industry has evolved over time, so too have the methods and approaches for designing the layout of automotive plants and facilities.

Nowadays, Indonesia is one of the largest automotive markets in Southeast Asia. The country has a mix of domestic and international manufacturers and a growing automotive system. Indonesia has focused on increasing local production and value addition, attracting foreign investment, and encouraging joint ventures with local companies. While Indonesia's automotive industry has experienced significant growth, it faces challenges such as infrastructure limitations and competition from other Southeast Asian countries. However, these challenges also present opportunities for further growth and development.

PT GMI is one of the automotive manufacturing companies established in Indonesia, with several production lines. The company manufactures car doors for four-wheeled commercial vehicles as one of its products. In the manufacturing of the front car door, there are several processes that are carried out continuously at each workstation. Currently, PT GMI is implementing production process efficiency measures to address a projected 10% increase in demand for car door manufacturing compared to the current demand. In response to this request, PT GMI is analyzing several aspects, including the factory layout. The current factory layout has limitations that can disrupt the output volume, particularly in the production of front car doors. The strategy is to cut material handling, which results in an estimate of 10% cost reduction.

A well-designed facility layout usually leads to improvements in the company's operational efficiency,

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which ultimately enhances the company's long-term success and sustainability (Kovács & Kot, 2017). According to previous research, factory layout involves the planning and arrangement of machines, equipment, material flow, and labor across different workstations (Yang & Lu, 2023). Effective organization in this area leads to greater efficiency and effectiveness in work processes.

Employing an efficient and thoughtfully designed layout in a factory is essential for ensuring smooth and effective production operations. An ideal factory layout can enhance workflow, lower production costs, and boost overall productivity. Computerized Relationship Layout Planning (CORELAP) is one approach that can be utilized to create an effective factory layout. CORELAP is a layout planning approach that emphasizes the connections between departments or work areas within a production facility (Lufika et al., 2021). This method accounts for the significance of closeness between departments to enhance operational efficiency. By leveraging CORELAP, layout planners can organize production facilities according to the significance of interdepartmental relationships, reducing travel distances and promoting smooth workflow.

Implementing CORELAP in factory layout design provides an organized and data-informed method for arranging departments and work areas. This approach enables factories to make the most of available space, enhance communication and teamwork, and establish a safe and pleasant workplace environment. In today's world of intense global competition, factories that can efficiently design layouts will gain a substantial competitive edge. CORELAP offers layout planners a powerful tool to accomplish this objective by offering clear direction in structuring production facilities based on distinct operational requirements (Jati et al., 2020).

Previous research has shown that CORELAP can aid in creating optimal factory layouts by considering the relationships between departments (Hakim & Istiyanti, 2015). This leads to a smoother and more efficient workflow. Other studies indicate that using CORELAP can decrease production costs by reducing the distance and time required to transport materials and products between departments (Tarigan et al., 2019). Other research also suggests that applying CORELAP can enhance employee productivity and overall operational efficiency (Muralidhar, 2018). CORELAP allows for flexible factory layout design, which can adjust to evolving production needs and market demands (Chakroun, Zribi, Hani, El Mhamedi, et al., 2022).

Additional studies have demonstrated that the CORELAP method contributes to more efficient use of space within the factory, including production areas and supporting facilities (Gómez et al., 2003). CORELAP has been implemented across various industries such as automotive, electronics, and pharmaceuticals (Wilasto & Wibisono, 2023)(Hakim & Istiyanti, 2015). This research confirms that the method can be tailored to each industry's specific requirements. Another research has also noted positive effects from using CORELAP, including improved product quality, higher employee satisfaction, and increased company profits (Sundin et al., 2011).

This study aims to describe the comprehensive design of the factory and facility layout using the CORELAP method. To accomplish the factory layout design with CORELAP, supporting data such as the Operation Process Chart (OPC) is necessary. OPC serves as a diagram illustrating the steps or sequence of processes or operations, along with checks or inspections that materials undergo from the beginning until they become finished or semi-finished products (Muchlisin et al., 2022). Routing sheets are utilized to support the CORELAP method. A routing sheet is a document employed in the manufacturing process to guide and document the production flow of a product (Saffanah et al., 2023). This document details all the steps involved in producing a product, from raw materials to the final product. Routing sheets also aid in planning and managing production and can be used to monitor and refine production processes over time.

The upcoming data to support the analysis involves examining the necessary floor area. The Area Requirement refers to the space allocated for managing materials or executing production processes (Janani & Sankar, 2021). Assessing floor area needs during the design of factory layouts is crucial for optimizing the efficiency and productivity of manufacturing activities. The subsequent data provided is the Activity Relationship Chart (ARC). ARC is a method for organizing the connections between workstations based on the intensity of their activity relationship, represented by a scoring system using letters and numbers that explain the rationale behind the password (Wahyukaton & Affifah, 2019).

The upcoming data pertains to the Activity Relationship Diagram (ARD). ARD is a diagram that maps the relationship between activities based on proximity priorities to minimize handling costs (Permatasari et al., 2020). In this analysis, the CORELAP method is employed to optimize the factory layout design. CORELAP was chosen for its ability to prioritize relationships between spaces, enabling the placement of closely related areas near each other. Additionally, CORELAP provides a clear square layout that is easily understandable for both non-experts and professionals (Jati et al., 2020). The ARD results from the CORELAP method can be utilized as supporting data in creating an Area Allocated Diagram (AAD). AAD serves as a comprehensive template that encompasses area usage details (Zedgenizov et al., 2020). For visual representation, the final factory layout design analysis can be illustrated through a visual template displaying the outcomes.

The CORELAP method is a systematic approach used for designing an efficient factory layout. This approach involves the analysis of various factors such as material flow, equipment placement, and workstations to optimize productivity and minimize costs (Li et al., 2023). By utilizing the CORELAP method, manufacturers can effectively allocate resources, streamline production processes, and enhance overall operational efficiency (Bazargan-Lari, 1999). This method considers the current situation and future development plans of the enterprise, analyzing material and non-material flows to obtain a relation graph for all workshops in the company.

This approach is particularly beneficial for small and medium-sized enterprises (SMEs) that aim to increase productivity and make continuous improvements (Cahyani et al., 2023). With the CORELAP method, SMEs can achieve significant reductions in material handling costs, waste, and the need for large capital investments. Additionally, the CORELAP method emphasizes collaboration and integration in the factory layout design process.

The CORELAP method is expected to facilitate the design of efficient and effective factory layouts. The purpose of this study is to develop a new layout using the CORELAP method. This approach allows for the design and implementation of changes to the facility layout, resulting in an optimal layout that addresses the challenges at hand. Factory layout design is based on reference data as a foundation. The focus of this research is the production line for manufacturing front doors. This particular focus was chosen to illustrate the product design process and identify the necessary facilities that need to be considered during the design stage.

2. Research Methods

The research commenced with a literature review to enhance understanding and insight into the foundational theories needed to address the issues. Alongside the literature review, a field study was conducted to examine the assembly process of the car's front door. The findings from both studies will help identify the necessary processes for manufacturing the car door. Literature and field studies were conducted simultaneously because both are essential as a preliminary foundation for initiating the research.

The CORELAP method is a constructive algorithm used to develop new layouts by focusing on the Total Closeness Rating (TCR), which measures the proximity between departments or facilities as depicted in the Activity Relationship Chart (ARC). This method depends entirely on the TCR calculations to determine the placement of facilities, enabling it to design and apply changes to the facility layout for optimal solutions to existing challenges (Chakroun, Zribi, Hani, Elmhamedi, et al., 2022). To guide the factory layout design process, it's established that the production demand for car front doors is 8 units per hour, operating at an efficiency level of 87%.

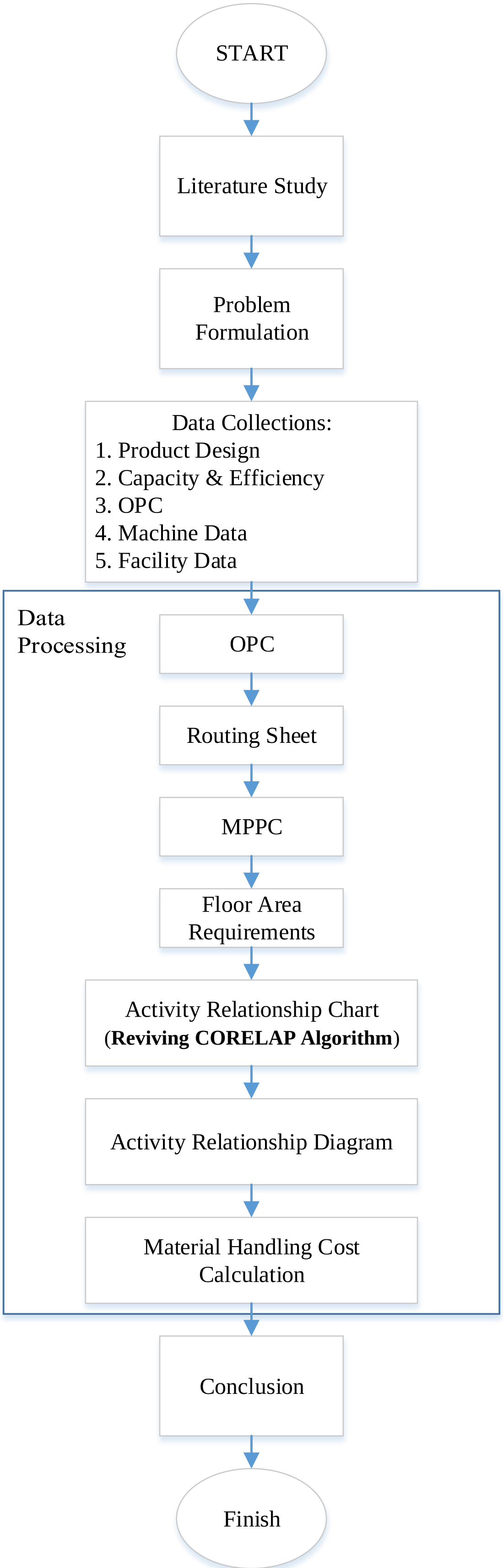

Figure 1: Research Flow Chart

The technical drawing or design of the car's front door was created initially to establish a reference for the production process required to manufacture the car door.

This research gathers data from the Operation Process Chart (OPC), machine facility data, as well as data related to facility staff and production services. This information serves as a foundation for applying the CORELAP method, which requires calculating routing sheets and floor area within the production area. Additionally, data regarding floor area for production facilities, services personnel, storage, warehouse, and other facility spaces is necessary. This input data will be processed using the CORELAP method through a series of stages.

The initial phase involves creating an Activity Relationship Chart (ARC) that examines the connections between each existing department. Following this, the CORELAP method is employed, with the results guiding the design of an Area Allocation Diagram (AAD). During the CORELAP processing, the Total Closeness Rating (TCR) is calculated based on the relationships between departments as depicted in the ARC data (Jati et al., 2020). The CORELAP method involves several steps for completion.

First, calculate the Total Closeness Rating (TCR) for each department. Choose one of the departments with the highest TCR and place it first. If there are departments with the same TCR, prioritize the one with the larger area; if the areas are the same, choose the department with the lowest number. Next, select a department with an "A" relationship to the already placed department. If there are multiple such departments, pick the one with the highest TCR; if TCRs are equal, any choice is acceptable. Repeat this process until all departments are placed. If there are no departments with an "A" or "E" relationship with the already placed departments, proceed with the "I" or "O" relationships, as well as "U" or "X."

Once the Activity Relationship Diagram (ARD) is created using the CORELAP method, the Area Allocated Diagram (AAD) and the overall design template for the factory and facility layout can be finalized. The process of designing the factory layout for manufacturing car front doors begins with data collection and proceeds with data analysis using the CORELAP method, including the creation of ARC and AAD. This is followed by calculating production flow distance and conducting an in-depth efficiency evaluation. By meticulously executing each phase, the final factory layout design aligns well with production requirements.

3. Results and Discussion

The collected data pertains to and supports the assessment of factory design using the CORELAP method. This data, which includes simulation models, is used to represent the setup of a new factory that manufactures front doors.

3.1 Technical Drawing

Technical drawings are a set of car front door component illustrations that offer a detailed description of an object or construction (Süße & Putz, 2021). These drawings serve as a means of communication in engineering, containing information about an object to be produced according to specific standards. Staying up to date with technology requires specialized skills and knowledge. The purpose of these drawings is to precisely convey the designer's intent, minimizing mistakes during planning, production, assembly, and inspection stages. Technical drawings must be interpreted objectively, necessitating the use of standards as guidelines for consistent and precise interpretation. These standards ensure uniformity and accuracy in understanding the drawings.

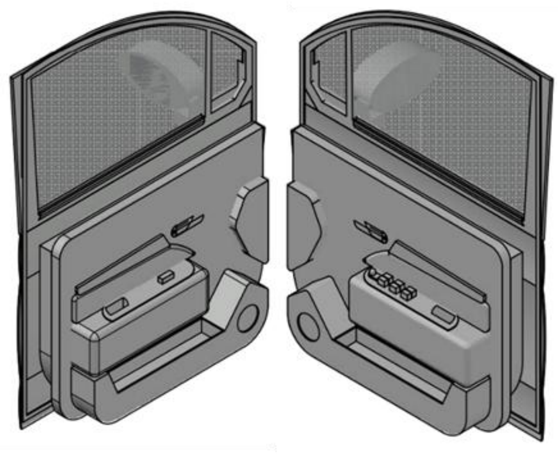

Figure 2: Car Front Left and Right Door Product Design

3.2 Operational Process Chart (OPC)

Operation Process Chart, commonly referred to as an OPC, is a graphical representation of the sequence and details of all operations, inspections, time allowances, and materials used for a process or production (Yang & Lu, 2023). It is designed to provide a clear and concise overview of all the steps involved in a workflow or manufacturing process. The chart typically includes symbols that represent different types of activities such as operations or inspections and connects them in the order they occur. This visualization is useful for understanding and analyzing the flow of work through a system and identifying areas for improvement or potential bottlenecks. Here is the data on the key components and raw materials for manufacturing front car doors:

Table 1: The Main Components and Raw Materials for Car Front Doors

No	Material	Part Name	Auxilary Materials
1	Iron Plate	Outer Body	-
2	Iron Plate	Inner Body	-
3	Iron Plate	Inner Body Plate	-
4	Iron Pipe (d=25mm)	Inner Body Pipe	-
5	Iron Plate	Front Pipe Holder	-
6	Iron Plate	Back Pipe Holder	-
7	Plastics	Inner Handle Base	-
8	Plastics	Inner Handle Lock	-
9	Plastics	Inner Handle Switch	-
10	Iron Plate	Main Regulator Plate	-
11	Iron Plate	Second Regulator Plate	-

No	Material	Part Name	Auxilary Materials
12	Iron Plate	Lower Regulator Rail	-
13	Iron Plate	Third Regulator Plate	-
14	Iron Plate	Upper Regulator Rail	-
15	Iron Plate	Window Holder	-
16	Iron Plate	Door Trim Support	-
17	Plastics	Door Trim Base	-
18	Plastics	Door Trim List	-
19	Plastics	Door Trim Pad	Cloth and Glue
20	Plastics	Door Trim Pocket	-
21	Plastics	Arm Rest Cover	-
22	Plastics	Inner Handle Cover	-
23	Plastics	Outer Handle	-
24	Plastics	Inner Cover Mirror	-

Table 1 provides data for summarizing the analysis of the OPC front car door design, which is displayed in Table 2.

Table 2: OPC Summary of Car Front Door Designs

No	Activity	Symbol	Total	Time (Minutes)
1	Operation	○	88	39.380
2	Checking	□	24	4.700
3	Storage	▼	1	0.000
	Total		113	44.080

3.3 Routing Sheet

Based on the OPC for manufacturing car front doors, the next step in planning the factory layout is to develop a Routing Sheet. This sheet is essential for identifying the required number of machines and estimating the parts needed to achieve the target quantity of finished products (Saffanah et al., 2023).

Table 3: Routing Sheet

No	Machine/Tools Name	Fab	Sub Assy	Main Assy	Total
1	Bench & Tools	0	4	0	4
2	Manual (Hand)	0	0	0	0
3	Manual (Hand), Stand & Visual Control	0	0	3	3
4	Cutting Machine	14	0	0	14
5	Welding Machine	0	1	0	1
6	Molding Machine 1600T	1	0	0	1
7	Molding Machine 350T	10	0	0	10
8	Stamping Progressive Machine 1600T	2	0	0	2
9	Stamping Progressive Machine 200T	2	0	0	2
10	Stamping Machine 1000T	15	0	0	15
11	Stamping Machine 1600T	4	0	1	5
12	Stamping Machine 200T	7	0	0	7
13	Stand & Tools	0	3	0	3
14	Stand & Visual Control	3	0	1	4
15	Tools	0	8	0	8
16	Tools & Visual Control	1	0	0	1
17	Tools, Stand & Visual Control	0	0	10	10
18	Visual Control	0	0	0	0
	Total Machine				90

3.4 Multi Product Process Chart (MPPC)

MPPC is a diagram that depicts the steps materials, including raw and auxiliary materials, will go through, outlining operations, inspections, storage, and categorizing stages into Rough Lumber, Fabrication, Sub Assembly, and Main Assembly, each identified separately. In essence, MPPC serves as a map that illustrates machine usage based on data from the Routing Sheet (Methalina et al., 2021). According to the MPPC analysis, the assessment of the number of machines in the main assembly line is presented in Figure 1, while the machine data used is summarized in Table 4.

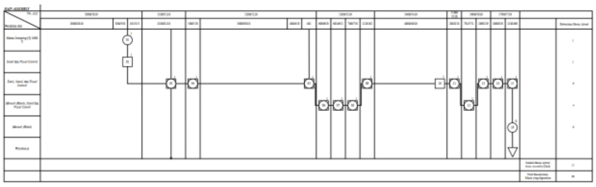

Figure 1: MPPC of main assembly line

Table 4: MPPC Summary

No	Activity	Number of Machine
1	Rough Lumber	0
2	Fabrication	59
3	Sub Assy 1	9
4	Sub Assy 2	7
5	Main Assy	15
	Total Machine	90

3.5 Floor Area Requirements

The analysis of floor area requirements involves further examination to estimate the land needed for activities within the production section. This calculation considers the raw materials to be prepared, the machinery or equipment utilized, and the final goods manufactured (Kanishka & Acherjee, 2023). The objective of analyzing floor area requirements is to evaluate the space necessary for the planned facilities. A key aspect in planning floor area requirements is establishing an efficient workflow system. Factors to be considered include machine space, operator work areas, storage space for materials pre- and post-processing, as well as areas for material handling activities. This essential area is then supplemented with a 50% buffer to facilitate smooth production operations (Zhao et al., 2022). Below are the findings from the analysis of production floor area requirements in the factory:

Table 5: Production Floor Area Requirements

No	Facility Name	Area (m^2)
1	Receiving	31
2	Storage	125
3	Fabrication	1808
4	Sub-Assy	180
5	Main Assy	258
6	Warehouse	158

7	Shipping	39
8	Engineering Div. Room	22
9	PPIC Div. Room	40
10	Production Div. Room	33
11	Maintenance Div. Room	22
12	Quality Control Room	33
13	Forklift Garage	60
14	Scrap Area	18
15	Air Handling	18
16	Changing Room (Male)	54
17	Changing Room (Female)	30
18	Toilet (Male)	37
19	Tolilet (Female)	24
20	Equipment Room	36
21	Polyclinic	36
22	PPE Room	52

3.6 Activity Relationship Chart (ARC)

The Activity Relationship Chart is employed to design facility layouts, focusing on the level of qualitative interactions between activities, which often rely on subjective assessments for each facility. The establishment of ARC was grounded on considerations of proximity, as depicted in table 6 and table 7 showed value of the degree of closeness. The outcomes from the ARC analysis are illustrated in Figure 3.

Table 6: Justification for the Proximity of ARC (Source: Apple, 2016 - modificated)

Code	Justification
1	Workflow Sequence
2	Dusty Area
3	Possibly a Stuffy Room
4	Similar Employee
5	Facilitate communication and coordination
6	Makes monitoring and controlling easier

Table 7: Value of The Degree of Closeness (Source: Apple, 2016)

Code	Remark	Value	Color Code
A	Absolute	4	Red
E	Very Important	3	Orange
I	Important	2	Green
O	Normal	1	Blue
U	Not Important	0	White
X	Undesirable	-1	Brown

From the ARC findings, a tabulation summarizing the degrees of proximity is generated, as illustrated in Table 8, indicating 18 instances of absolute closeness and 143 instances of negligible closeness.

Table 8: Results of assessing the degree of closeness

	Code	Percentage Range (%)	Minimal Range	Maximal Range
N = n(n-1)/2 N = 26(26-1)/2 = 26(25)/2 = 325 *Closeness	A	2 – 6	7	18
	E	3 – 10	10	33
	I	5 – 15	17	49
	O	10 – 25	33	82
	U	25 – 60	82	195
	X	Depend	Depend	Depends

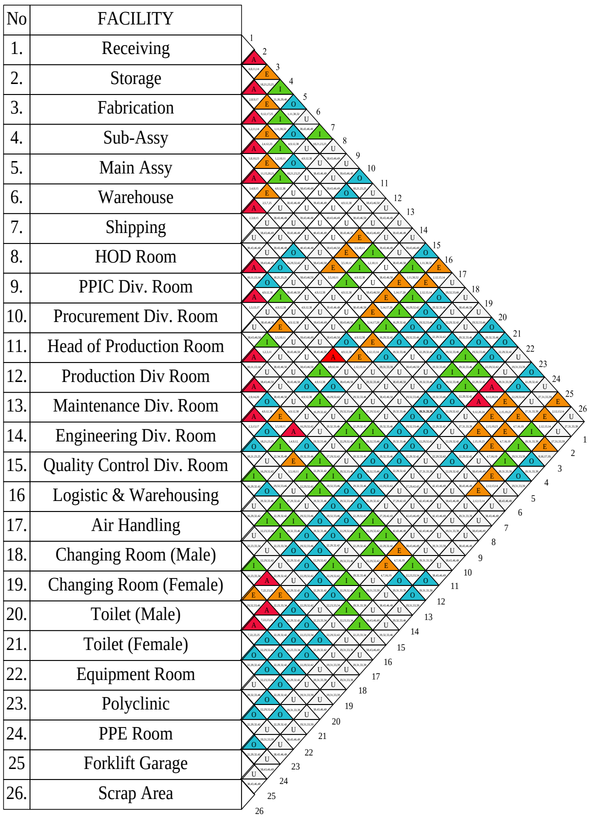

Figure 3: Activity Relationship Chart of Front Car Door Product

3.7 Activity Relationship Diagram (ARD)

In Activity Relationship Diagram (ARD) analysis, the CORELAP technique is employed to assess the proximity of facility layouts, focusing on the Place Rating derived from Total Closeness Rating (TCR) computations. Details regarding TCR calculations are available in Table 9.

Table 9: Total Closeness Rating (TCR) Results

No	Facility Name	TCR	Place Rating
1	Receiving	21	7
2	Storage	23	5
3	Fabrication	39	1
4	Sub-Assy	34	2
5	Main Assy	29	3
6	Warehouse	24	4
7	Shipping	22	6
8	Engineering Div. Room	6	21
9	PPIC Div. Room	19	11
10	Production Div. Room	36	8
11	Maintenance Div. Room	30	10
12	Quality Control Room	33	9
13	Forklift Garage	23	13
14	Scrap Area	-3	22
15	Air Handling	18	14
16	Changing Room (Male)	28	12
17	Changing Room (Female)	13	19
18	Toilet (Male)	16	18
19	Toilet (Female)	17	17
20	Equipment Room	18	16
21	Polyclinic	14	20
22	PPE Room	8	15

The TCR calculation results provide data that serves as a guide for processing with the CORELAP algorithm, resulting in a layout as depicted in Figure 4.

14	1	2	15	8	
13	4	3	10	9	18
21	5	6	12	11	19
	20	7	16	22	17

Figure 4: Alternative Layout Configuration for Car Front Door Production

Figure 3 provides a visual representation of the layout positions of each facility outlined in Table 9. Facilities with closely related degrees of proximity are depicted as being positioned near one another due to their interconnected relationship. Conversely, facilities with a high level of proximity are not situated close to each other, considering certain requirements, such as areas prone to noise, dust, or those not correlating with production flow.

The results derived from the CORELAP algorithm's calculations are depicted in the form of an Area Allocation Diagram (AAD), showcasing calculated placement applications. Alterations in layout occur due to variations in the floor area of each facility as shown in Figure 5. The layout design incorporates the consideration of aisles within the production section, serving as additional transportation pathways for material handling, particularly with the use of hand trucks as proposed by the company. The design outcomes for the production section aim to alleviate current company challenges, specifically addressing issues like insufficient floor area to accommodate growing machinery demands and the irregular placement of individual machines.

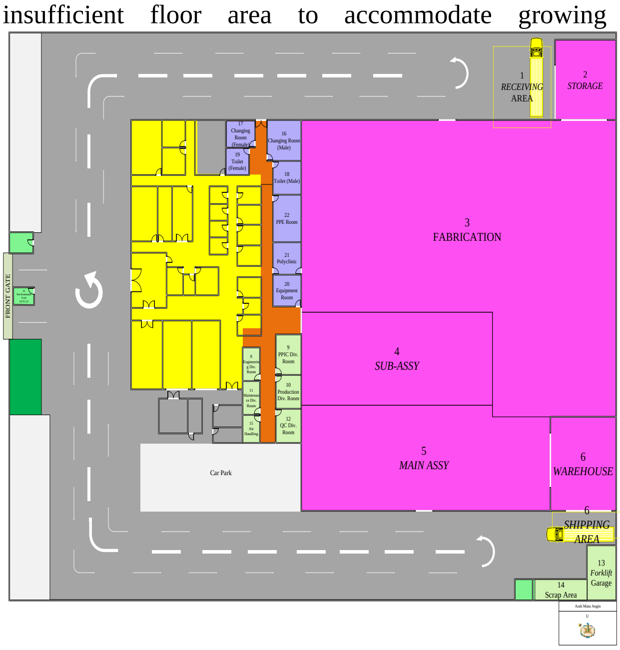

Figure 5: Overall Layout

3.8 Material handling Cost Calculation

Material handling costs require careful consideration of material volume, frequency, and movement distance. A less systematic material handling system implementation can lead to significant issues and disruptions in the production process (Kathmann et al., 2023). Through effective factory layout planning, such as minimizing backtracking and reducing the distance between material movement instances, material handling costs can be minimized (Halim et al., 2015). Figure 10 illustrates the results of material handling cost calculations for car door products. Based on calculations, showed that total material handling cost is Rp 763,959.

Table 10: Material Handling Costs Calculations

No	Section	Total Cost (Rp)	Total Cost/Day	Cumulative Cost (Rp)
1	Receiving to Storage (auxiliary materials)	4,741	2,370	2,370
2	Receiving to Storage (main materials)	2,021	1,010	3,381
3	Storage to Fabrication to Following Fabrication	473,648	236,824	240,205
4	Fabrication to Sub-Assy	424,504	212,252	452,457
5	Sub-Assy to Main Assy	620,401	310,200	762,658
6	Main Assy to Warehouse	1,792	864	763,523
7	Warehousing to Shipping	872	436	763,959
Total Material Handling Cost/Day (Rp)				**763,959**

4. Conclusion

The factory layout planning for producing car front doors reveals a capacity of 8 units per hour with an efficiency level of 87%. Utilizing the CORELAP approach, a factory layout design meeting these criteria can be achieved. Additionally, material handling costs are computed to determine the expenses involved in establishing a car front door production facility, totaling IDR 763,959. This study aims to demonstrate the process of designing a factory focused on automotive products, particularly car door products. The research progresses by considering and comparing alternative approaches to CORELAP. Furthermore, detailed production material flows are necessary to establish more efficient flow patterns based on available data. The limitations of this article stem from the design's emphasis on material handling factors. The company's management requested and provided input to further explore the potential effectiveness of the planning. The next recommendation is to closely monitor the implementation of planning steps in layout arrangement, considering all factors that impact the design outcomes.

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