Facility layout design of bag and apparel factory with systematic layout planning and computerized relative allocation of facilities technique method

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ABSTRACT

The high market attractiveness index and competitive position made Dewi Media Lestari invest in building a new factory. The factory specifically is used to produce convection products and apparel. Development is carried out using a systematic layout planning and computerized relative allocation of facilities technique. The objective of this research is to obtain an ideal layout that can minimize the distance between departments. As a result, there are nine departments with a total area of 385 m² consisting of 18 m² loading dock department, 36 m² raw material department, 86 m² cutting department, 42 m² branding department, 21 m² screen printing department, 105 m² sewing department, 28 m² finishing department, 28 m² packing department, and 21 m² warehouse department. Material handling costs for the initial layout produced using the systematic layout planning method are IDR 29,808.95 per day. After adjusting with Computerized Relative Facility Allocation Technique, the most ideal final layout was produced with minimal material handling costs of IDR 24,411.40 per day.

1. INTRODUCTION

Dewi Media Lestari (DML) is an industry that serves the manufacture of various kinds of fully customized products. Business development is supported by four determining factors, they are top management support, effective communication, employee engagement, and sufficient resources [1]. Apart from that, the company has also carried out portfolio analysis. Portfolio analysis is a decision-making process by making a trade-off between commercial and non-commercial values [2]. The results of the portfolio analysis show that the market attractiveness index is 81.4 and the competitive position index is 88.8. Based on these findings, the most appropriate offensive strategy to use is to invest to grow, while the most appropriate defensive system is to protect position. Invest to grow is a strategy of investing resources to increase market share and company revenue in the global arena [3]. Building new factories with more specific segmentation is a good step to create economic growth [4].

The factory that DML will build is a factory that produces various types of bags and apparel, which has been DML's sales force with the largest gross profit. The types of bags that will be produced in the new factory

include various types of lined bags, pouches, totebags, backpacks, slingbags,, and waistbags. Meanwhile, the apparel that will be produced includes T-shirts, polo shirts, shirts, training sets and trousers, vests, jackets, hats, and jerseys. DML is a Make-to-order (MTO) industry, so the design of the factory layout is based on monthly sales targets. This sales target is determined based on historical sales data for two years based on several considerations and the capabilities of the DML marketing team. The development of the MTO industry requires clear identification of the key factors that influence the implementation of the third step of the Theory of Constraint (TOC), namely adapting the system to bottlenecks [5].

Factory design must be made rationally by emphasizing needs at the first level and limited resources at the second level. Factory layout arrangements affect employee productivity [6]. So the factory layout should be designed to reduce material transportation distances, provide sufficient space for machines and operators, minimize production costs, reduce work accident rates, reduce material waiting times, and facilitate production operations [7]. Good facility design will provide high efficiency in a factory [8]. A good production facility layout must be able to avoid backflow, no bottlenecks, and a minimum frequency of material movement [9]. The same thing was conveyed by Pratiwi et al that the main objective of designing a factory layout is to minimize total costs consisting of construction costs, installation of machines and equipment, Material Handling Costs (MHC), production costs, storage costs, and other related costs [10].

This research aims to design the layout and facilities of a factory that produces various types of bags and apparel in a production area that can minimize MHC. The desired result is a layout of the factory production area in the form of a Final Area Allocation Diagram which can minimize the distance between priority departments.

2. MATERIALS AND METHODS

Facility layout design is defined as the process of arranging and organizing production facilities by paying attention to various elements such as relationships between departments, material flow, cost-effectiveness and efficiency, material safety, workforce, and production facilities [11]. Facility layout design combines space allocation and equipment rearrangement as such that total operating cost is minimised [12]. Facility layout design is used for the arrangement of equipment and machinery in a factory irrespective of whether it is established or contemplated to allow the quickest flow possible at minimal cost and material handling in processing the product from receiving raw material to the final shipment [13].

Facility layout design in this research was carried out using the Systematic Layout Planning (SLP) method combined with the Computerized Relative Allocation of Facilities Technique (CRAFT) to obtain the ideal layout. SLP is a layout design method that can collaborate scenarios between production and material flows, transportation, warehousing, and assembly in several production activities [14]. SLP was developed by Richard Muther and has been widely used in various industries to improve efficiency, productivity, and quality [15]. This theory consists of four main steps, including: collecting data about activities, space, and equipment involved in the production process or warehouse; creating an activity relationship chart that shows how often and how important the relationships between different activities are; creating a space relationship diagram that shows the shape and size of space required for each activity and equipment, as well as the relationship between different spaces; create alternative layouts that meet technical, economic and ergonomic criteria, and select the best layout based on evaluation and comparison [15]. CRAFT method is a layout optimization method by considers the size of a certain area and the relationship between departments in one unit [16]. CRAFT algorithm also is based on a matrix of interdepartmental flow and cost [17]. CRAFT method is intended to minimize MHC by minimizing the distance between departments, generally, those that have a highly close relationship [18].

This research was carried out empirically by calculating the area and production machine requirements according to production needs. Required data such as operating time for each process and each product is obtained by observing three repetitions of an operator with a certain level of ability and working environment. The cycle time obtained will then be converted into standard time by paying attention to adjustment factors and allowances. Observation and determination of standard time are intended so that in the process of determining the number of machines or facilities needed by the company it can be in accordance with needs. The incompatibility will have an impact on the area required in the production area so the research will not be representative of the company's needs. The solution steps used in this research are presented at Figure 1. Table 1, Table 2, Table 3, and Table 4 presented below.
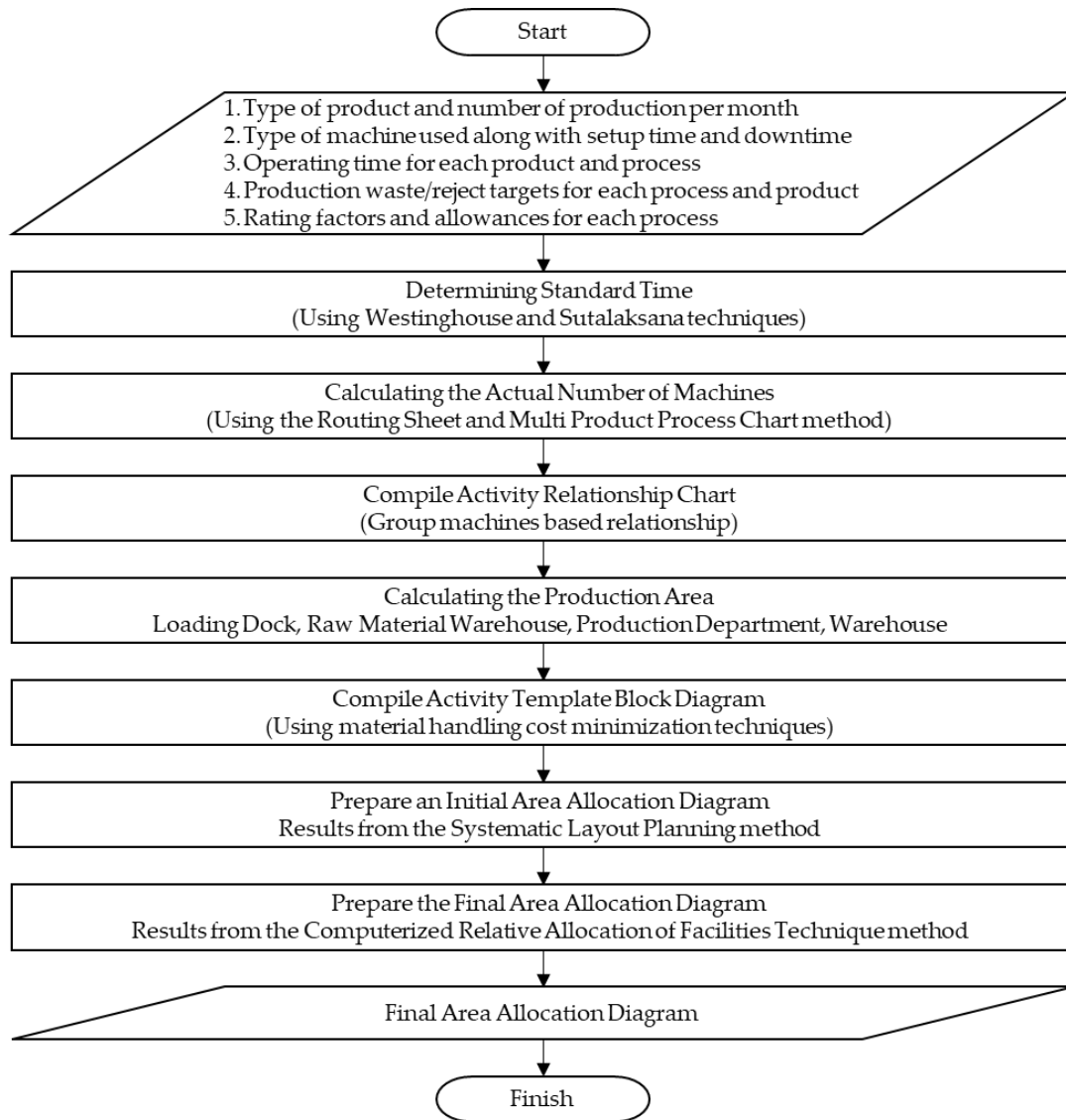
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   ╱  1. Type of product and number of production per month         ╲
  ╱   2. Type of machine used along with setup time and downtime      ╲
 ╱    3. Operating time for each product and process                   ╲
╱     4. Production waste/reject targets for each process and product   ╲
╲     5. Rating factors and allowances for each process                ╱
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    │            Department, Warehouse                          │
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    │        Compile Activity Template Block Diagram           │
    │ (Using material handling cost minimization techniques)    │
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Figure 1. Research flowchart

Table 1. Type of product and number of productions per month

Type of Product	Brev	Production Qty
Standard Furring Bag	F1	10.000 pcs
Banner Furing Bag	F2	1.000 pcs
Mica Furring Bag	F3	1.000 pcs
Calico Pouch	P1	300 pcs
D300/D600 Pouch	P2	500 pcs
Natural Canvas Pouch	P3	700 pcs
Cordura Pouch	P4	500 pcs
Gail Pouch	P5	200 pcs
Vinyl Pouch	P6	1.000 pcs
Mica Pouch	P7	200 pcs
Micro Pouch	P8	500 pcs
Furring Pouch	P9	1.000 pcs
Calico Totebag	T1	1.000 pcs
D300/D600 Totebag	T2	300 pcs
Canvas Totebag	T3	1.000 pcs
Natural Canvas Totebag	T4	500 pcs

Table 2. Type of product and number of productions per month (Conitinued)

Type of Product	Brev	Production Qty
Gail Totebag	T5	700 pcs
Cordura Totebag	T6	300 pcs
Oxford Totebag	T7	300 pcs
Taslan Totebag	T8	300 pcs
Stringbag	T9	300 pcs
Mica Totebag	T10	200 pcs
T-Shirt	A1	700 pcs
Polo Shirt	A2	700 pcs
Shirt	A3	400 pcs
Training Set	A4	200 pcs
Vest	A5	200 pcs
Jacket	A6	200 pcs
Hat	A7	300 pcs
Jerseys	A8	200 pcs
Backpack	B1	700 pcs
Slingbag	B2	500 pcs
Waistbag	B3	300 pcs

Table 3. Type of machine, setup time, and downtime

Type of Machine	Brev	*Setup Time* (m/d)	*Down Time* (m/d)
Cutting Table	CT	0,08	0,00
Pond Machine	PM	15,00	10,00
Engraving Machine	EM	23,00	12,50
Debossed Machine	DM	45,00	0,06
Six-Head Embroidery Machine	SH	60,00	1,71
Screen Printing	SP	0,00	0,00
Sewing Machine	SM	14,00	0,29
Serger	SG	8,00	0,29
Buttons Machine	BM	4,00	0,29
Knob Table	KT	0,00	0,00
Sorting Table	ST	0,00	0,00
Ironing Table	IT	3,00	0,00
Packing Table	PT	0,00	0,00

Table 4. Operating time for each product and process

Type of Product	CT	PM	EM	DM	SH	SP	SM	SG	BM	KT	ST	IT	PT
F1	0,11	0,00	0,00	0,00	0,00	0,18	0,00	0,00	0,00	0,00	0,83	0,00	0,10
F2	0,15	0,00	0,00	0,00	0,00	0,18	0,00	0,00	0,00	0,00	0,83	0,00	0,10
F3	0,16	0,00	0,00	0,00	0,00	0,18	0,00	0,00	0,00	0,00	0,83	0,00	0,10
P1	0,13	0,00	0,00	1,00	0,00	0,22	5,00	0,08	0,00	0,00	1,00	0,00	0,10
P2	0,15	0,00	0,93	1,00	0,67	0,18	5,00	0,00	1,00	0,00	1,00	0,00	0,10
P3	0,17	0,05	0,93	1,00	0,67	0,22	6,00	0,08	1,00	0,00	1,00	0,00	0,10
P4	0,15	0,00	0,93	1,00	0,00	0,18	5,00	0,00	1,00	0,00	1,00	0,00	0,10
P5	0,16	0,00	0,93	1,00	0,67	0,18	8,00	0,00	1,00	0,00	1,00	0,00	0,10
P6	0,16	0,10	0,93	1,00	0,00	0,18	16,00	0,00	1,00	0,80	1,00	0,00	0,10
P7	0,19	0,00	0,00	1,00	0,00	0,18	6,00	0,00	0,00	0,00	1,00	0,00	0,10
P8	0,15	0,00	0,93	1,00	0,00	0,18	5,00	0,00	1,00	0,00	1,00	0,00	0,10
P9	0,13	0,00	0,00	1,00	0,00	0,18	5,00	0,00	0,00	0,00	1,00	0,00	0,10
T1	0,32	0,00	0,93	0,00	0,00	0,22	5,00	0,17	0,00	0,00	1,08	0,00	1,00
T2	0,37	0,00	0,93	1,00	0,00	0,18	5,00	0,00	0,00	0,00	0,63	0,00	1,00

Table 5. Operating time for each product and process (Continued)

Type of Product	CT	PM	EM	DM	SH	SP	SM	SG	BM	KT	ST	IT	PT
T3	0,32	0,10	0,93	1,00	0,00	0,22	10,00	0,17	0,00	0,00	0,63	0,00	1,00
T4	0,32	0,10	0,93	1,00	0,00	0,22	10,00	0,17	0,00	0,00	0,63	0,00	1,00
T5	0,47	0,00	0,93	1,00	0,67	0,18	12,00	0,00	0,00	0,00	1,08	0,00	1,00
T6	0,37	0,00	0,93	1,00	0,00	0,18	5,00	0,00	0,00	1,00	0,63	0,00	1,00
T7	0,32	0,00	0,93	0,00	0,00	0,18	5,00	0,17	0,00	0,00	0,63	0,00	1,00
T8	0,32	0,00	0,00	0,00	0,00	0,18	5,00	0,00	0,00	0,00	1,08	0,00	1,00
T9	0,15	0,00	0,00	1,00	0,00	0,18	16,50	0,00	0,00	0,00	0,63	0,00	1,00
T10	0,45	0,00	0,00	1,00	0,00	0,22	10,00	0,00	0,00	1,00	1,08	0,00	1,00
A1	5,00	0,00	0,00	0,00	0,00	0,35	10,00	10,00	0,00	0,00	1,67	3,00	0,50
A2	5,00	0,00	0,00	0,00	1,33	0,35	10,00	10,00	3,00	0,00	1,67	3,00	0,50
A3	10,00	0,00	0,00	0,00	1,00	0,35	180,00	20,00	8,00	0,00	1,67	5,00	0,50
A4	7,00	0,00	0,00	0,00	1,00	0,35	180,00	20,00	3,00	0,00	1,67	5,00	0,50
A5	5,00	0,00	0,00	0,00	1,33	0,35	180,00	20,00	8,00	0,00	1,67	5,00	0,50
A6	10,00	0,00	0,00	0,00	1,33	0,35	180,00	20,00	8,00	0,00	1,67	3,00	0,50
A7	2,00	0,00	0,00	0,00	0,83	0,35	15,00	5,00	0,00	1,00	0,63	0,00	0,50
A8	5,00	0,00	0,00	0,00	0,00	0,00	10,00	10,00	0,00	0,00	1,67	3,00	0,50
B1	5,00	0,50	0,93	1,00	1,00	0,18	30,00	0,00	0,00	1,00	1,67	0,00	0,50
B2	5,00	0,50	0,93	1,00	1,00	0,18	30,00	0,00	0,00	1,00	1,67	0,00	0,50
B3	5,00	0,50	0,93	1,00	1,00	0,18	30,00	0,00	0,00	1,00	1,67	0,00	0,50

Table 6. Waste for each product and process

Type of Product	CT	PM	EM	DM	SH	SP	SM	SG	BM	KT	ST	IT	PT
F1	0,50%	0,00%	0,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
F2	0,50%	0,00%	0,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
F3	0,50%	0,00%	0,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
P1	0,50%	0,00%	0,00%	1,00%	0,00%	1,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,10%
P2	0,50%	0,00%	1,00%	1,00%	1,00%	1,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,10%
P3	0,50%	0,50%	1,00%	1,00%	1,00%	1,00%	2,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,10%
P4	0,50%	0,00%	1,00%	1,00%	0,00%	1,00%	1,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,10%
P5	0,50%	0,00%	1,00%	1,00%	1,00%	1,00%	2,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,10%
P6	0,50%	0,50%	1,00%	1,00%	0,00%	1,00%	2,00%	0,00%	1,00%	1,00%	0,00%	0,00%	0,10%
P7	0,50%	0,00%	0,00%	1,00%	0,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
P8	0,50%	0,00%	1,00%	1,00%	0,00%	1,00%	1,00%	0,00%	1,00%	0,00%	0,00%	0,00%	0,10%
P9	0,50%	0,00%	0,00%	1,00%	0,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T1	0,50%	0,00%	1,00%	0,00%	0,00%	1,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T2	0,50%	0,00%	1,00%	1,00%	0,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T3	0,50%	0,50%	1,00%	1,00%	0,00%	1,00%	2,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T4	0,50%	0,50%	1,00%	1,00%	0,00%	1,00%	2,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T5	0,50%	0,00%	1,00%	1,00%	1,00%	1,00%	2,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T6	0,50%	0,00%	1,00%	1,00%	0,00%	1,00%	1,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,10%
T7	0,50%	0,00%	1,00%	0,00%	0,00%	1,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T8	0,50%	0,00%	0,00%	0,00%	0,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T9	0,50%	0,00%	0,00%	1,00%	0,00%	1,00%	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,10%
T10	0,50%	0,00%	0,00%	1,00%	0,00%	1,00%	1,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,10%
A1	1,00%	0,00%	0,00%	0,00%	0,00%	1,00%	5,00%	5,00%	0,00%	0,00%	0,00%	0,00%	0,10%
A2	1,00%	0,00%	0,00%	0,00%	1,00%	1,00%	5,00%	5,00%	1,00%	0,00%	0,00%	0,00%	0,10%
A3	1,00%	0,00%	0,00%	0,00%	1,00%	1,00%	5,00%	5,00%	3,00%	0,00%	0,00%	0,00%	0,10%
A4	1,00%	0,00%	0,00%	0,00%	1,00%	1,00%	5,00%	5,00%	1,00%	0,00%	0,00%	0,00%	0,10%
A5	1,00%	0,00%	0,00%	0,00%	1,00%	1,00%	5,00%	5,00%	3,00%	0,00%	0,00%	0,00%	0,10%
A6	1,00%	0,00%	0,00%	0,00%	1,00%	1,00%	5,00%	0,00%	3,00%	0,00%	0,00%	0,00%	0,10%
A7	1,00%	0,00%	0,00%	0,00%	1,00%	1,00%	3,00%	1,00%	0,00%	1,00%	0,00%	0,00%	0,10%
A8	1,00%	0,00%	0,00%	0,00%	0,00%	0,00%	5,00%	5,00%	0,00%	0,00%	0,00%	0,00%	0,10%
B1	1,00%	0,50%	1,00%	1,00%	1,00%	1,00%	5,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,10%
B2	1,00%	0,50%	1,00%	1,00%	1,00%	1,00%	5,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,10%
B3	1,00%	0,50%	0,00%	1,00%	1,00%	1,00%	5,00%	0,00%	0,00%	1,00%	0,00%	0,00%	0,10%

3. RESULTS

3.1. Determinations of standard time

Cycle time is time obtained based on observations with one or more repetitions. Cycle time is the average time it takes to process a product starting from receiving to completion [19]. The cycle time is shown in Table 3. Normal time is the cycle time that has been given an adjustment factor (rating factor). The adjustment factors used in this research use the Westinghouse technique, where each person has a different level of skill, level of effort, condition, and consistency [20]. Referring to the Westinghouse Table, observations were made on an operator with skill level: Good (C1: +0.06), effort level: Very Good (B2: +0.08), working conditions: Good (C: +0.02), and consistency: Very Good (B: +0.03). Under these conditions, the factor rating determined is 0.19.

Standard time is the time needed for an operator to complete his work with an average level of ability [21]. Standard time is calculated based on normal time given an allowance factor. An operator uses slack to unwind, meet personal needs, and do unexpected things outside of work [20]. The amount of allowance is determined based on what work is done. Aspects taken into account in the allowance factor include:

a. The energy expended in the cutting, pond, embroidery, and screen printing processes is light; very light processes for engraving, debossing, sewing, overlocking, buttons, knobs, sorting, and ironing; while the packing process is light.
b. The working attitude in the pond, embroidery, screen printing, and packing processes is standing on both legs, while in other processes the working attitude is sitting.
c. Normal work movements in all processes.
d. Eye fatigue during the sorting process, namely continuous viewing with changing focus, while in other processes the viewing is intermittent.
e. Normal workplace temperature.
f. The workplace atmosphere is good.
g. Good work environment.
h. Normal personal needs.

Table 5 is presented below. After determining the adjustment factors and allowances, the standard time is presented in Table 6.

Table 7. Allowance for each process

Process	a	b	c	d	e	f	g	h	All
CT	5	1,5	0	3	3	0	1	3	16,5
PM	5	1,5	0	3	3	0	1	3	16,5
EM	2	0,5	0	3	3	0	1	3	12,5
DM	2	0,5	0	3	3	0	1	3	12,5
SH	5	1,5	0	3	3	0	1	3	16,5
SP	5	1,5	0	3	3	0	1	3	16,5
SM	2	0,5	0	3	3	0	1	3	12,5
SG	2	0,5	0	3	3	0	1	3	12,5
BM	2	0,5	0	3	3	0	1	3	12,5
KT	2	0,5	0	3	3	0	1	3	12,5
ST	2	0,5	0	16	3	0	1	3	25,5
IT	2	0,5	0	3	3	0	1	3	12,5
PT	3	3	0	3	3	0	1	3	16

Table 8. Standard time for each product and process

Type of Product	CT	PM	EM	DM	SH	SP	SM	SG	BM	KT	ST	IT	PT
F1	0,16	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00	1,33	0,00	0,14
F2	0,21	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00	1,33	0,00	0,14
F3	0,23	0,00	0,00	0,00	0,00	0,25	0,00	0,00	0,00	0,00	1,33	0,00	0,14
P1	0,19	0,00	0,00	1,36	0,00	0,31	6,80	0,11	0,00	0,00	1,60	0,00	0,14
P2	0,21	0,00	1,27	1,36	0,95	0,25	6,80	0,00	1,36	0,00	1,60	0,00	0,14
P3	0,24	0,07	1,27	1,36	0,95	0,31	8,16	0,11	1,36	0,00	1,60	0,00	0,14

Table 9. Standard time for each product and process (Continued)

Type of Product	CT	PM	EM	DM	SH	SP	SM	SG	BM	KT	ST	IT	PT
P4	0,21	0,00	1,27	1,36	0,00	0,25	6,80	0,00	1,36	0,00	1,60	0,00	0,14
P5	0,22	0,00	1,27	1,36	0,95	0,25	10,88	0,00	1,36	0,00	1,60	0,00	0,14
P6	0,22	0,14	1,27	1,36	0,00	0,25	21,76	0,00	1,36	1,09	1,60	0,00	0,14
P7	0,26	0,00	0,00	1,36	0,00	0,25	8,16	0,00	0,00	0,00	1,60	0,00	0,14
P8	0,21	0,00	1,27	1,36	0,00	0,25	6,80	0,00	1,36	0,00	1,60	0,00	0,14
P9	0,18	0,00	0,00	1,36	0,00	0,25	6,80	0,00	0,00	0,00	1,60	0,00	0,14
T1	0,46	0,00	1,27	0,00	0,00	0,31	6,80	0,23	0,00	0,00	1,73	0,00	1,42
T2	0,53	0,00	1,27	1,36	0,00	0,25	6,80	0,00	0,00	0,00	1,00	0,00	1,42
T3	0,46	0,14	1,27	1,36	0,00	0,31	13,60	0,23	0,00	0,00	1,00	0,00	1,42
T4	0,46	0,14	1,27	1,36	0,00	0,31	13,60	0,23	0,00	0,00	1,00	0,00	1,42
T5	0,67	0,00	1,27	1,36	0,95	0,25	16,32	0,00	0,00	0,00	1,73	0,00	1,42
T6	0,53	0,00	1,27	1,36	0,00	0,25	6,80	0,00	0,00	1,36	1,00	0,00	1,42
T7	0,46	0,00	1,27	0,00	0,00	0,25	6,80	0,23	0,00	0,00	1,00	0,00	1,42
T8	0,46	0,00	0,00	0,00	0,00	0,25	6,80	0,00	0,00	0,00	1,73	0,00	1,42
T9	0,21	0,00	0,00	1,36	0,00	0,25	22,44	0,00	0,00	0,00	1,00	0,00	1,42
T10	0,64	0,00	0,00	1,36	0,00	0,31	13,60	0,00	0,00	1,36	1,73	0,00	1,42
A1	7,13	0,00	0,00	0,00	0,00	0,50	13,60	13,60	0,00	0,00	2,66	4,08	0,71
A2	7,13	0,00	0,00	0,00	1,90	0,50	13,60	13,60	4,08	0,00	2,66	4,08	0,71
A3	14,25	0,00	0,00	0,00	1,43	0,50	244,80	27,20	10,88	0,00	2,66	6,80	0,71
A4	9,98	0,00	0,00	0,00	1,43	0,50	244,80	27,20	4,08	0,00	2,66	6,80	0,71
A5	7,13	0,00	0,00	0,00	1,90	0,50	244,80	27,20	10,88	0,00	2,66	6,80	0,71
A6	14,25	0,00	0,00	0,00	1,90	0,50	244,80	27,20	10,88	0,00	2,66	4,08	0,71
A7	2,85	0,00	0,00	0,00	1,19	0,50	20,40	6,80	0,00	1,36	1,00	0,00	0,71
A8	7,13	0,00	0,00	0,00	0,00	0,00	13,60	13,60	0,00	0,00	2,66	4,08	0,71
B1	7,13	0,71	1,27	1,36	1,43	0,25	40,80	0,00	0,00	1,36	2,66	0,00	0,71
B2	7,13	0,71	1,27	1,36	1,43	0,25	40,80	0,00	0,00	1,36	2,66	0,00	0,71
B3	7,13	0,71	1,27	1,36	1,43	0,25	40,80	0,00	0,00	1,36	2,66	0,00	0,71

3.2. Calculation of actual number of machines

A Routing Sheet is a tabulation of the steps involved in producing certain components and the necessary details of related matters [22]. A Routing sheet is a technique used to determine the number of machines needed for each part of a product in a certain amount [23]. The determination of machines on the routing sheet is based on the number of products produced within a certain period, taking into several important factors, including standard product processing time for each process, waste targets per product and process, and machine availability time [24]. There are three important components in routing sheets, namely the Number Required (NR), the Number that Must be Prepared (NMP), and the Theoretical Number of Machines (TNM). NR is a production target within a certain time period. Meanwhile, TNM is the number of machines required for one process. NMP and TNM are obtained by equations (1) and (2).

$$NMP = \frac{NR}{1 - \%waste} \tag{1}$$

$$TNM = \frac{standard\ time\ x\ NMP}{Available\ time\ x\ Availability\ x\ Conversion\ factor} \tag{2}$$

Available time is the amount of time that can be used for the machine to operate during one day, 14 working hours or 840 minutes. Meanwhile, the conversion factor is the value for converting quantity. The production target is set in one month, with 25 working days, so the conversion factor is 25. Multi Product Process Chart (MPPC) is a flow diagram that shows the relationship between many products and the many processes they go through. MPPC also shows the production process that several product components go through on the same production machine[25]. The information obtained from MPPC is the Actual Number of Machines (ANM) required to be provided at the factory. Table 7 is presented below.

The number of machines is mentioned in Table 7 is the machine requirement in a day. To save the development budget, including the procurement of machinery, it was decided that the new factory would operate in two shifts. If the factory needs two machines of the same type and specifications in one day, only need to purchase one is enough for requirements in two shifts. The same thing applies to an odd number of

machines, such as three cutting tables, so only need to procure two machines. This will have an impact on the area required in the factory. That number of machines is then used in calculating the production area.

Table 10. Actual number of machines

Type of Machine	TNM	ANM
Cutting Table	2,12	3
Pond Machine	0,08	1
Engraving Machine	0,59	1
Debossed Machine	0,69	1
Six Head Embroidery Machine	0,42	1
Screen Printing	0,37	1
Sewing Machine	23,31	24
Serger	2,65	3
Buttons Machine	0,83	1
Knob Table	0,20	1
Sorting Table	1,65	2
Ironing Table	0,61	1
Packing Table	0,59	1

3.3. Create activity relationship chart

Activity Relationship Chart (ARC) is a qualitative facility layout design method used to relationships between groups [26]. ARC is commonly used in determining relationships between machines or departments, especially when preparing facility layouts using the SLP method. The disadvantage of ARC is that it has a high level of subjectivity depending on the basic needs of each factory, so in its implementation ARC will be combined with other quantitative measurement techniques to test relationships between departments [26]. Reasons for the proximity are shown at Table 11. ARC is symbolized by several letters shown at Table 12. ARC of machines shown at Figure 2.

Table 11. Reason for proximity

Number	Reason
1	Material flow
2	Similar functions
3	Convenience
4	Frequency
5	No relation
6	Safety

Table 12. Symbolized of ARC

Code	Meaning
A	Absolutely nearby
E	Very important nearby
I	Important nearby
O	Normal
U	Unimportant nearby
X	Not allowed adjacent

3.4. Calculation of production area

Machines that are production resources are grouped based on their close relationship into one department. Machine grouping is based on the ARC presented in Figure 2, where machines that have an absolute (A) relationship will be grouped into one department. There are nine departments, including:
1. Loading Dock (LD) department is used for the process of receiving goods from outside to the raw material warehouse and for the process of sending goods from the warehouse to outside. The vehicle generally

used for receiving and sending goods is a colt diesel with a length of 4.59 meters and a width of 1.69 meters. So, at least an area of 6 x 3 meters or 18 m² is needed as a loading dock area.

2. Raw Materials (RM) warehouse department is used to store materials that will be used in the production process. To store the main material rack (rolled fabric) measuring 6.5 x 1.6 meters and storing supporting material racks measuring 4.5 x 0.5 meters, a raw material warehouse measuring 32.5 m² is required.
3. Cutting Table Department (CT) has 3 cutting tables and a pond machine.
4. Branding Department (BR) has an engraving machine, a debossing machine, and a six-head embroidery machine.
5. Screen Printing Department (SP) has a screen-printing table.
6. Sewing Department (SW) has 24 sewing machines.
7. Finishing Department (FN) has 3 serger machines, a button machine, and a knob table.
8. Packing Department (PK) has 2 sorting tables, an ironing table, and a packing table.
9. Warehouse Department (WH) is used to store finished goods before being sent to consumers. The area of the warehouse department which contains shelves for finished goods requires an area of 21.12 m².
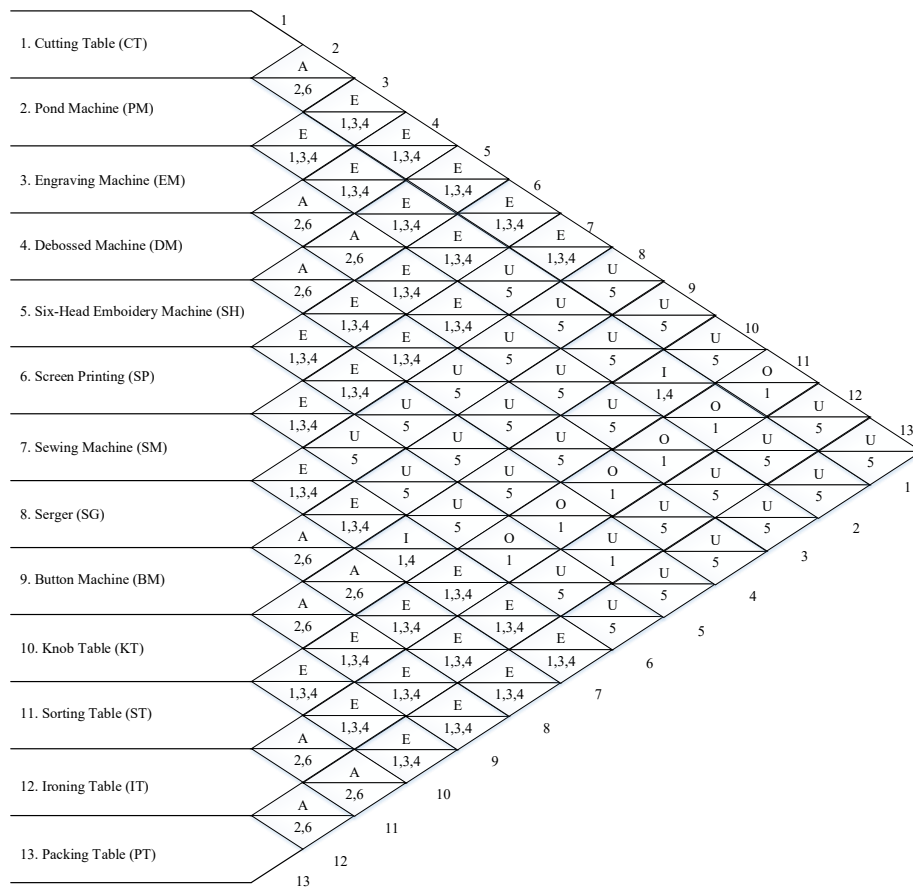
Figure 2. Activity Relationship Chart of Machines

Calculating the floor area of the production department needs to take into the size of the machine, the size of incoming and outgoing materials, the operator area, the maintenance area, and the transportation area. Incoming and outgoing materials, operator and maintenance area, and material handling area are the allowance that we prepared for production movement. The movement in a factory is a must to be fulfilled properly because it is a way for the operations to run well and be comfortable. The material handling tool used is a hand trolley measuring 74 x 48 cm, so the required aisle width is 50 cm. Production department area presented at Table 13.

3.5. Calculation of initial material handling cost

If the material handling process takes too long, it will increase the costs the company has to incur [27]. Therefore, one of the principles of layout design is to minimize MHC. Minimizing MHC can be achieved by

shortening the material travel distance. In other words, every department that has high interaction is as close as possible. Determining the close relationship between departments is described in a priority matrix.

Table 13. Production department area

Dept	Machines	ANM	Machine		Incoming		Outgoing		Operator		Maintenance		Handling	Work Station			Dept Area (m²)
			P (m)	L (m)	P (m)	L (m)	P (m)	L (m)	P (m)	L (m)	P (m)	L (m)	L (m)	P (m)	L (m)	Area (m²)	
CT	CT	2	4	2	1	0,5	1	0,5	6	0,5	6	0,5	0,5	13	4	52	59
	PM	1	0,8	0,5	0,5	0,5	0,5	0,5	1,8	0,5	1,8	0,5	0,5	2,8	2,5	7	
BR	EM	1	1,5	1,2	0,5	0,5	0,5	0,5	2,5	0,5	2,5	0,5	0,5	3,5	3,2	11,2	41,04
	DM	1	0,8	0,8	0,5	0,5	0,5	0,5	1,8	0,5	1,8	0,5	0,5	2,8	2,8	7,84	
	SH	1	3,5	2	0,5	0,5	0,5	0,5	4,5	0,5	4,5	0,5	0,5	5,5	4	22	
SP	SP	1	4,5	1,2	0,5	0,5	0,5	0,5	5,5	0,5	5,5	0,5	0,5	6,5	3,2	20,8	20,8
SW	SW	12	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	21,4	2,5	53,5	53,5
FN	SG	2	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	4,4	2,5	11	24,5
	BM	1	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	2,7	2,5	6,75	
	KT	1	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	2,7	2,5	6,75	
PK	ST	1	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	2,7	2,5	6,75	20,25
	IT	1	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	2,7	2,5	6,75	
	PT	1	0,7	0,5	0,5	0,5	0,5	0,5	1,7	0,5	1,7	0,5	0,5	2,7	2,5	6,75	
Summary																	**219,09**

The priority matrix is determined based on the initial MHC calculation. The initial MHC calculation is based on the department area obtained in the previous stage. MHC is calculated by taking into possible material flows. Material flow must be able to describe the flow of material from the arrival of main and supporting raw materials to product delivery. Summary of production department area presented at Table 14.

Table 14. Summary of production department area

Department	Area (m²)
Loading Dock	18
Raw Material	32,5
Cutting Department	59
Branding Department	41,04
Screen Printing Department	20,8
Sewing Department	53,5
Finishing Department	24,5
Packing Department	20,25
Warehouse	21,12
Total	290,71

Initial of MHC created in five categories, they are Furring, Pouch, Totebag, Aparel, and Bag categories. Below, I present an example to calculated the MHC for furring in Table 15. MHC is obtained by equations (3) to (5). Cost of hand trolley each meter is 9,73 IDR. This number was obtained based on calculations carried out by Ika et al [28].

$$MHC = Moving\ distance \times Moving\ frequency \times cost\ of\ material\ handling\ per\ meter \qquad (3)$$

$$Moving\ distance = \sqrt{Area\ of\ initial\ point} + \sqrt{Area\ of\ destination\ point} \qquad (4)$$

$$Moving\ frequency = \frac{Quantity\ of\ moving\ part}{Capacity\ of\ material\ handling\ each\ moving} \qquad (5)$$

Table 15. Calculated of MHC for furring

Initial	Flow	Material		Qty	Transportation				Transported			CAP	DIS	FRE	CPM	MHC
					Name	L1	W1	H1	L2	W2	H2					
	LD-RM	Main material	5	roll of fabric	Hand trolley	74	48	50	160	25	25	4	4,97	2	9,73	96,75
LD	LD-RM	Support material	10	arrival box	Hand trolley	74	48	50	30	30	30	12	4,97	1	9,73	48,38
	LD-PK	Product	480	pcs product	Hand trolley	74	48	50	54	46	0,5	200	4,37	3	9,73	127,60

Furring: Monthly output = 12.000 pcs, 1 month = 25 days, daily output = 480 pcs product

- CAP is capacity of hand trolley each moving (unit).
  - CAP = (roundup$\frac{L1}{L2}$) x (round$\frac{W1}{W2}$) x (round$\frac{H1}{H2}$)
  - CAP = (roundup$\frac{74}{160}$) x (round$\frac{48}{25}$) x (round$\frac{50}{25}$) = 4 unit
- DIS is moving distance for each flow (meter).
  - DIS (LD-RM) = $\sqrt{LD\ area} + \sqrt{LD\ RM}$
  - DIS (LD-RM) = $\sqrt{18} + \sqrt{32,5}$ = 4,97 meter
- FRE is moving frequency for each flow (times).
  - FRE (LD-RM) = $roundup(\frac{Qty\ material}{CAP})$
  - FRE (LD-RM) = $roundup(\frac{5}{4})$ = 2 times
- CPM is cost per meter. The value is 9,73 IDR [28].
- MHC is total cost for each flow (IDR)
  - MHC = DIS x FRE x CPM
  - MHC = 4,97 x 2 x 9,73 = 96,75 IDR

MHC calculations are carried out from the arrival of the material at the LD until the goods are stored at the WH. Summary of initial MHC for Furring, Pouch, Totebag, Aparel, and Bag presented on Table 16.

Table 16. Summary of initial MHC (IDR)

Initial	Flow	Furring	Pouch	Totebag	Apparel	Bag	Total
	LD-RM	96,75	96,75	96,75	96,75	96,75	483,75
LD	LD-RM	48,38	48,38	48,38	48,38	48,38	241,88
	LD-PK	127,60	-	-	-	-	127,60
	RM-CT	130,21	130,21	130,21	130,21	130,21	651,04
	RM-BR	58,90	58,90	58,90	58,90	58,90	294,51
RM	RM-SP	49,92	49,92	49,92	49,92	49,92	249,61
	RM-SW	63,32	63,32	63,32	63,32	63,32	316,60
	RM-FN	51,82	51,82	51,82	51,82	51,82	259,08
	RM-PK	49,63	49,63	49,63	49,63	49,63	248,14
	PT-BR	68,54	68,54	68,54	68,54	68,54	342,68
	PT-SP	119,11	59,56	59,56	59,56	59,56	357,34
CT	PT-SW	-	72,95	145,91	145,91	72,95	437,72
	PT-FN	61,45	61,45	61,45	61,45	61,45	307,25
	PT-PK	237,05	-	-	-	-	237,05
BR	BR-SW	-	66,75	66,75	66,75	66,75	267,00
	BR-PK	53,06	-	-	-	-	53,06
SP	SP-SW	-	57,77	57,77	57,77	57,77	231,09
	SP-PK	88,16	-	-	-	-	88,16
SW	SW-FN	-	59,66	119,33	178,99	59,66	417,65
	SW-PK	287,38	57,48	114,95	172,43	57,48	689,72
FN	FN-SW	-	59,66	59,66	59,66	59,66	238,66

<div align="center">**Table 17**. Summary of initial MHC (IDR) (Continued)</div>

Initial	Flow	Furring	Pouch	Totebag	Apparel	Bag	Total
	FN-PK	45,97	45,97	91,95	137,92	45,97	367,78
PK	PK-WH	132,75	44,25	44,25	398,25	132,75	752,26
WH	WH-LD	128,99	43,00	43,00	386,98	128,99	730,97
	Total MHC per day						8.390,58

Intial MHC value was transformed into From-to-Chart (FTC) total costs. FTC total costs is a facility layout design technique that refers to the total cost of moving production materials [29]. FTC total cost is shown at Figure 3.

F\T	LD	RM	CT	BR	SP	SW	FN	PK	WH	Total
LD		725,63						127,60		853,23
RM			651,04	294,51	249,61	316,60	259,08	248,14		2.018,96
CT				342,68	357,34	437,72	307,25	237,05		1.682,03
BR						267,00		53,06		320,06
SP						267,00		88,16		355,16
SW							417,65	689,72		1.107,38
FN						238,66		367,78		606,44
PK									752,26	752,26
WH	730,97									730,97
Total	730,97	725,63	651,04	637,18	606,95	1.526,98	983,98	1.811,51	752,26	8.426,49

<div align="center">**Figure 3**. FTC total costs</div>

Based on Figure 3, an outflow matrix and an inflow matrix can be determined. The outflow matrix shows the percentage of closeness between departments based on the outflow (forward) of material, while the inflow matrix shows the percentage of closeness between departments based on the inflow (backward) of material. Outflow matrix and Inflow matrix shown consecutively at Figure 4 and Figure 5.

F\T	LD	RM	CT	BR	SP	SW	FN	PK	WH	Total
LD		0,85						0,15		1,00
RM			0,32	0,15	0,12	0,16	0,13	0,12		1,00
CT				0,20	0,21	0,26	0,18	0,14		1,00
BR						0,83		0,17		1,00
SP						0,75		0,25		1,00
SW							0,38	0,62		1,00
FN						0,39		0,61		1,00
PK									1,00	1,00
WH	1,00									1,00
Total	0,86	0,85	0,76	0,75	0,71	1,79	1,15	2,12	0,88	9,00

<div align="center">**Figure 4**. Outflow matrix</div>

F\T	LD	RM	CT	BR	SP	SW	FN	PK	WH	Total
LD		1,00						0,07		1,07
RM	0,00		1,00	0,46	0,41	0,21	0,26	0,14		2,48
CT				0,54	0,59	0,29	0,31	0,13		1,86
BR						0,17		0,03		0,20
SP						0,17		0,05		0,22
SW							0,42	0,38		0,81
FN						0,16		0,20		0,36
PK									1,00	1,00
WH	1,00									1,00
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	9,00

<div align="center">**Figure 5**. Inflow matrix</div>

Based on the outflow and inflow matrix, a priority matrix is obtained. The preparation of the priority matrix is based on the outflow matrix first. If there are two or more departments with the same outflow value, the next step is determined based on the inflow matrix. The priority matrix is shown at Figure 6.

Dept	Priotity											
	1		2		3		4		5		6	
LD	RM	0,85	PK	0,15								
RM	CT	0,32	SW	0,16	BR	0,15	FN	0,13	PK	0,12	SP	0,12
CT	SW	0,26	SP	0,21	BR	0,20	FN	0,18	PK	0,14		
BR	SW	0,83	PK	0,17								
SP	SW	0,75	PK	0,25								
SW	PK	0,62	FN	0,38								
FN	PK	0,61	SW	0,39								
PK	WH	1,00										
WH	LD	1,00										

Figure 6. Priority matrix

3.6. Compilation of activity template block diagram

Activity Template Block Diagram (ATBD) is arranged based on a priority matrix at Figure 6. ATBD will be used as an initial guide in determining the factory layout. ATBD is shown in Figure 7.

Figure 7. ATBD

3.7. Compilation of initial area allocation diagram

Area Allocation Diagram (AAD) is an initial depiction of the layout obtained from ATBD. The number of cells in each department in the AAD is adjusted to the area of each department which is shown in Table 14. AAD is shown in Figure 8.

Initial AAD shown in **Figure 8** is then iterated with the help of Win-QSB software to obtain iterations that are able to minimize MHC. The technique used to determine the most optimal layout is the Computerized Relative Allocation of Facilities Technique (CRAFT) method. CRAFT is carried out with a functional layout solution to minimize the distance between priority departments. The distance measurement carried out at this stage is rectilinear distance, where the distance between departments is measured based on the difference in horizontal distance and the difference in vertical distance from the center point of the two departments [30].

3.8. Comparison of material handling costs

Aim of this paper is to design the layout and facilities of a factory that can minimize MHC. Initial AAD shown at Figure 8 gave MHC IDR29.807,95 per day. Significant MHC reduction can be achieved by exchanging locations between departments to provide minimal distance between closely interconnected departments. This exchange process is carried out computerized using the CRAFT method. AAD 1st iteration gave MHC IDR24.439,62 per day, whreas AAD 2nd iteration gave MHC IDR24.411,40 per day. AAD 2nd iteration is the final iteration because AAD iteration provides a larger MHC value and a layout irregularity where the layout shown does not comply with the principles in the ATBD. Comparison of distances between departments and MHC in the initial AAD, AAD 1st iteration, and final AAD is shown at Table 18. They are obtained from

computerized distance calculations using the Win-QSB software. From those distances, we can calculated the MHC with the same steps with Table 15 and Table 16.
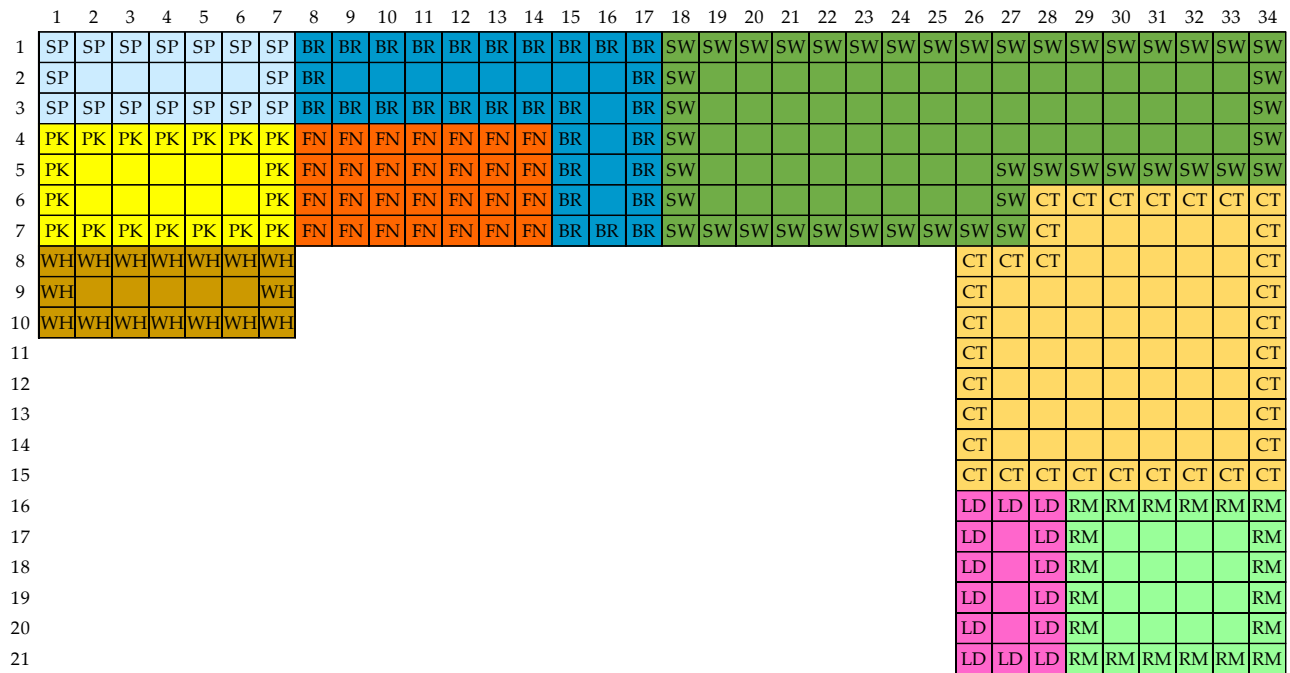
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
1	SP	SP	SP	SP	SP	SP	SP	BR	BR	BR	BR	BR	BR	BR	BR	BR	BR	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW
2	SP						SP	BR									BR	SW																SW
3	SP	SP	SP	SP	SP	SP	SP	BR	BR	BR	BR	BR	BR	BR	BR		BR	SW																SW
4	PK	PK	PK	PK	PK	PK	PK	FN	FN	FN	FN	FN	FN	FN	BR		BR	SW																SW
5	PK						PK	FN	FN	FN	FN	FN	FN	FN	BR		BR	SW									SW	SW	SW	SW	SW	SW	SW	SW
6	PK						PK	FN	FN	FN	FN	FN	FN	FN	BR		BR	SW									SW	CT	CT	CT	CT	CT	CT	CT
7	PK	PK	PK	PK	PK	PK	PK	FN	FN	FN	FN	FN	FN	FN	BR	BR	BR	SW	SW	SW	SW	SW	SW	SW	SW	SW	CT							CT
8	WH	WH	WH	WH	WH	WH	WH																			CT	CT	CT						CT
9	WH						WH																			CT								CT
10	WH	WH	WH	WH	WH	WH	WH																			CT								CT
11																										CT								CT
12																										CT								CT
13																										CT								CT
14																										CT								CT
15																										CT	CT	CT	CT	CT	CT	CT	CT	CT
16																										LD	LD	LD	RM	RM	RM	RM	RM	RM
17																										LD		LD	RM					RM
18																										LD		LD	RM					RM
19																										LD		LD	RM					RM
20																										LD		LD	RM					RM
21																										LD	LD	LD	RM	RM	RM	RM	RM	RM

Figure 8. Initial AAD

Table 18. Comparison of AAD

Flow	Distance (m)			Material Handling Cost (IDR)		
	Initial	1st iteration	Final iteration	Initial	1st iteration	Final iteration
LD-RM	4,5	4,5	4,5	437,85	437,85	437,85
LD-RM	4,5	4,5	4,5	218,93	218,93	218,93
LD-PK	36	36	36	1.050,84	1.050,84	1.050,84
RM-PT	9,15	12,57	12,57	890,30	1.223,06	1.223,06
RM-BR	33,5	9,5	9,5	1.629,78	462,18	462,18
RM-SB	44	20,52	21	2.140,60	998,30	1.021,65
RM-JH	21	32,5	32,4	1.021,65	1.581,13	1.576,26
RM-FN	33,5	33,5	33,5	1.629,78	1.629,78	1.629,78
RM-PK	40,5	40,5	40,5	1.970,33	1.970,33	1.970,33
PT-BR	24,35	8,19	8,19	1.184,63	398,44	398,44
PT-SB	34,85	7,95	8,43	2.034,54	464,12	492,14
PT-JH	11,85	19,93	19,83	691,80	1.163,51	1.157,68
PT-FN	24,35	20,93	20,93	1.184,63	1.018,24	1.018,24
PT-PK	31,35	27,93	27,93	1.220,14	1.087,04	1.087,04
BR-JH	12,5	23	22,9	486,50	895,16	891,27
BR-PK	12	31	31	116,76	301,63	301,63
SB-JH	23	11,97	11,4	895,16	465,87	443,69
SB-PK	3,5	20,79	22,5	68,11	404,57	437,85
JH-FN	16,17	6,04	5,7	1.101,34	411,38	388,23
JH-PK	23,17	13,04	12,7	2.705,33	1.522,55	1.482,85
FN-JH	16,17	6,04	5,7	629,34	235,08	221,84
FN-PK	7	7	7	544,88	544,88	544,88
PK-WH	3,5	3,5	3,5	578,94	578,94	578,94
WH-LD	32,5	32,5	32,5	5.375,83	5.375,83	5.375,83
Total				**29.807,95**	**24.439,62**	**24.411,40**

The results of the AAD final iteration shown in Figure 9.

Figure 9. Final AAD

Based on Table 18, it is known that final AAD at Figure 9 is the best layout because that layout provides the least MHC. MHC results from initial AAD to final AAD decreased by IDR 5.396,55 or 18.1%. This is relatively influential considering that production runs every day, and savings in just one year are already at IDR 1.618.964,97.

4. DISCUSSION

DML has purchased a plot of land on which a building is located and is in an unsuitable condition for use. To save on factory construction costs, it was decided to retain the foundation that was still in use. It can be extended if necessary because the land remains open in the front area. This is what lies behind the initial shape of the AAD shown in Figure 8. When viewed from Figure 8, the current dimensions of the building lie at coordinates (1.1) to (7.34) and (28.8) to (34.16). On this basis, the initial shape of the AAD appears in Figure 8, which expands in the frontal region at coordinates (8,1) to (7,10), (26.8) to (27.21), and from (28.17) to (34.21). The area of the building to be constructed is 385 m² because the current building will be maintained, and it only needs an expansion of 84 m². This is certainly very important in terms of saving development costs.

This consideration is also the reason why the SLP method is used. The SLP method is suitable for the construction of new buildings, even though it uses existing foundations, the area distribution for each department is still very flexible so it is very possible to use this SLP method. As a benchmark, we use the CRAFT method using Win-QSB software to analyze the initial layout results based on MHC.

The observations made are not limited to operator observations but also consider several things. The rating factor according to Westinghouse and the allowance determined based on the actual conditions that occurred in the old factory is the same reference in the construction of the new factory. The products discussed and allocation calculated in this research was only 33 products. They are products that have had a high level of demand from January 2020 until this research was conducted in August 2022. This limitation is intended to facilitate the calculation process in this research. Besides that, the quantity mentioned in Table 1 is the average quantity. There are several months, usually around August to November when there will be a surge in demand. This has also been discussed together with company stakeholders. If there is excessive demand, overtime hours will be applied, so that in carrying out the construction, the budget for construction and procurement of machinery can be reduced.

The final AAD shown in Figure 9 is the most representative result for the objective of building a new factory. Aside from saving construction costs by up to 458%, the design also complies with the principles of

distribution between departments with strong relationships. This will shorten the distance traveled resulting in cheaper moving costs. Another effect is that the operator's productivity becomes higher because he does not have to make unnecessary movements. At this point, the factory design is capable of implementing three of eight lean manufacturing principles simultaneously. Waiting, waiting for the next steps or process caused by unfinished materials in before steps. Transportation, waiting for materials to be moved from one place to another because of the relatively long distance. And extra motion, where the operator experiences insignificant motions.

ATBD matrix which is transformed into AAD is not only based on MHC minimization. Indirectly, the preparation of the layout is also based on discussions and trade-offs between heads of production departments to accommodate comfort in working. Based on Figure 9. Final AAD, total area for production plant is 385 m² consisting of 18 m² loading dock department, raw material department 36 m², cutting department 86 m², branding department 42 m², screen printing department 21 m², sewing department 105 m², finishing department 28 m², packing department 28 m², and warehouse department 21 m². If you look more closely, there is a slight difference between the areas mentioned in Table 14. Summary of production department area and the areas produced according to the final AAD. This is because the scale used in the final AAD from the start was deliberately made even to make it easier for the actual building construction process. However, this is a matter of joint consideration and has been agreed upon by the factory owner.

5. CONCLUSION

The conclusion obtained from this research is the final AAD shown in Figure 9. The layout shown in Figure 9 provides the smallest MHC, IDR 24,411.40 per day with a total area of 385 m² consisting of 18 m² loading dock department, raw material department 36 m², cutting department 86 m², branding department 42 m², screen printing department 21 m², sewing department 105 m², finishing department 28 m², packing department 28 m², and warehouse department 21 m².

We recommend that for further research development, there will be an evaluation that assesses the suitability of layouts built based on certain standards. For example, using the automated layout design problem or other layout optimization algorithm approach. It would be even better if the evaluation included a better layout while still paying attention to existing limitations considering that the building has been built with the assumption that it can still be developed as long as there is no need to demolish the main building.

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