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Improving Layout of Electric Vehicle Production Facilities using CRAFT Method and CORELAP Algorithm (Case Study : Gadjahmada Airport Transporter Electric (GATe))

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This research aims to design an efficient and productivity-enhancing production facility layout in the context of the GATe Workshop, which specializes in the manufacture of electric cars. Electric cars are an increasingly important part of the global automotive industry with great potential to reduce carbon emissions and petroleum demand. Indonesia, as the world's largest nickel producer, has a unique opportunity to become a major player in the electric vehicle industry.
The methodology used includes work flow analysis, process maps, and modeling tools such as Computerized Relationship Layout Planning (CORELAP) algorithm, Computerized Relative Allocation of Facilities Technique (CRAFT) method, and Intuitive algorithm. The analysis resulted in several alternative designs for a more efficient facility layout. In addition, the recalculation of the number of workers in the product department supported the maximization of production capacity without significantly increasing operational costs.
The results of this study identified several wastes in the initial layout design of Workshop GATe, including long distances between departments that led to a high frequency of material movement. This waste had a significant impact on operational efficiency and productivity. Therefore, this study redesigned the layout of production facilities and the number of workers in each department to achieve optimal output values.

Keywords: Electric Car, Improvement, Facility Layout, CRAFT Method, CORELAP Algorithm, Intuitive Algorithm, Material Movement, Material Handling Cost, Labor Management.

INTRODUCTION

The vehicle industry is one of the industrial sectors that makes a major contribution to the national economy [1]. Environmental issues encourage people to start switching from petrol-powered vehicles to electric vehicles. Electric vehicles are a type of passenger vehicle that is partly (Hybrid Electric Vehicle (HEV)) or wholly (Battery Electric Vehicle (BEV)) driven by an electric motor [2]. Electric vehicles can reduce carbon pollution by 54% compared to the carbon emissions of gasoline-powered vehicles [3]. The adoption of electric vehicles is expected to reduce oil demand by 6.4 MMbpd by 2040 [4]. Currently, the growth trend and development speed of global electric cars is developing rapidly. Manufacturing systems must be able to produce products at low costs and high quality, and deliver products to customers on time [5].

The use of electric vehicles can begin in various fields, for example from private transportation to public transportation. Private vehicles that use electric power are private vehicles such as cars, bicycles, and Neighbourhood Electric Vehicles (NEV) or also called Low Speed Vehicles (LSV) [6]. In some places, electric public transportation comes in the form of buses with passenger vehicles.

The Indonesian government is actively welcoming the arrival of the era of electric cars. Gadjah Mada University (UGM) is one of the institutions that is starting to develop electric cars for special needs [7]. The electric car developed by UGM called the Gadjahmada Airport Transporter Electric (GATe) will be used for transportation at airports [8].

Designing the layout of facilities is one of the things that is very important for a company, considering its function is to support all activities that take place within the company to improve company performance so that the company can develop further [5]. Designing a good layout of company facilities will influence the smooth operation and activities that take place within the company and can also further optimize the space within the factory [9]. In addition, facility layout design will create more economical work facilities, thereby increasing operator performance [10]. In the industrial world, factory layout and production facilities and equipment are important factors in increasing company productivity.

The aim of this research is to design and evaluate GATe Car production systems and facilities so that GATe production facilities can achieve optimal production with the limitations of existing facilities.

LITERATURE REVIEW

Facility layout is an important factor in influencing a company's production productivity. The CORELAP method is used in convection companies to propose facility layout designs. This research can provide suggestions for designing a more effective and efficient facility layout in the use of more organized space, especially in the production area for placing machines, additional areas as a place for employee transportation, and transportation equipment for moving materials as well as the layout of production parts that can minimize the problem of inadequate floor use for increasing machine requirements [11].

The CORELAP method is also used to analyze the results of distance calculations and material handling costs which produce distances and material handling costs that are smaller compared to the existing layout [12]. The CORELAP method is used in designing the layout of office space facilities at the Faculty of Engineering. Based on the results of the completed data processing, a proposed layout of the Faculty of Engineering's office facilities was obtained using the CORELAP method. The resulting layout recommendations suggest improvements to the facilities of the Dean's Office, FE Administrative Office, Secretariat Office, and FE Finance Office which are located nearby based on the importance of working relationships in office activities and a better layout. Space is limited to the lecturer's room. The overall plan produced by the CORELAP method is that it can facilitate the coordination of working relationships between various FE office interests in accordance with the operational needs of the office unit and this space design can minimize the occurrence of distance transfers [13].

The research conducted at SME using the CORELAP method layout design obtained the smallest score value and the smallest or minimum material handling cost. From the results of calculations using the CORELAP method, 3 alternative proposed improvements were obtained. The 3rd alternative has the smallest score and material handling cost compared to the other alternatives. Selection of alternative layouts by considering the smallest material handling cost is due to reducing costs for SMEs. From the research results it can be concluded that alternative 3 can be chosen because the score is 26 and material handling cost is 5,304.59 in one day [14].

Graph theory and the CRAFT system are used in modifying existing coconut fiber mattress factories. By using graph theory, material handling costs can be reduced by up to 0.1% so that the CRAFT method can be adapted. Modifications using CRAFT were carried out using an add-in for Microsoft Excel developed by Jenson and Co. This new layout resulted in a reduction of 4.5% and 2.4% for total distance between departments and total distance traveled per day [15].

The research used the CRAFT algorithm to develop a new factory layout for a foundry company. The idea of developing this new layout is to reduce material handling costs as well as the distance traveled by material and material flow time from one department to another compared to the existing factory layout. It can be seen that the proposed layout developed using CRAFT reduces job travel distance by 34.9% compared to the existing plant layout design. Furthermore, this reduction in travel distance will result in a reduction in material handling costs of 34.9% [16].

The percentage of proximity-based scores performed by applying the Automated Layout Design Program (ALDEP) algorithm followed by the CRAFT repair routine methodology is better compared to the ALDEP construction routine alone. The better layout evaluation resulting from CRAFT resulted in an Adjacency Based Score percentage of 83% compared to 80% from ALDEP. There is also significant consistency between material handling costs and production lead times [17]. There is also significant consistency between material handling costs and production lead times.
Based on the research results of the proposed alternative layout using CRAFT, there was a reduction in total material movement costs of 9.21% per batch and the smallest total material movement costs were 7434,713 IDR per batch [18].

RESEARCH METHODS

The object of this research is the GATe electric vehicle production facility. The facilities regulated in this research are production facilities only. The factors considered in arranging facilities are combining the scope of material handling, level of efficiency, movement distance, total movement, transfer load, and facility design in the form of a new layout design.

In this research, CORELAP software is used as software to model development algorithms (construction algorithms), namely algorithms used to produce new layout designs that do not depend on or do not require an initial layout. Then used CRAFT Software as the software to help improve the layout of an existing facility by swapping two or more departments to help organize the facility into an optimal floor plan. Draw.io software is a tool to visualize charts and layout of production data. The research stage begins with the development of production supporting documents including product data such as bill of materials, routing sheets, Operation Process Chart, as well as process and material flow data such as REL diagrams, from-to-charts and flowcharts. In order to model and simulate the layout, FlexSim software is used based on existing data. Meanwhile, modeling, validation and validation of the resulting models are also tested.

The next stage is the calculation of the Total Layout Closeness Rating to evaluate the analysis from a qualitative perspective. The total closeness between departments of each layout is calculated by identifying the level of closeness in the layout which is then calculated and added up. Calculation of Total Distance for Material Movement Layout Calculation of the total distance of mass movement is an evaluation from a quantitative perspective, using a distance-based method through straight line calculations. Finally, determine the best method by analyzing material handling, efficiency level,

movement distance, total movement, and movement load.

EXPERIMENTAL RESULT AND DISCUSSION

The data used includes the sequence of the GATe car manufacturing process, processing time, raw materials and car components, and facility information (workshop size, number of workers, and number of machines). The location to be designed is in the Bugisan area with a building area of 300 m2. Figure 1 GATe car production facilities on the 1st floor and 2nd floor, while departmental needs can be seen in Table 1.

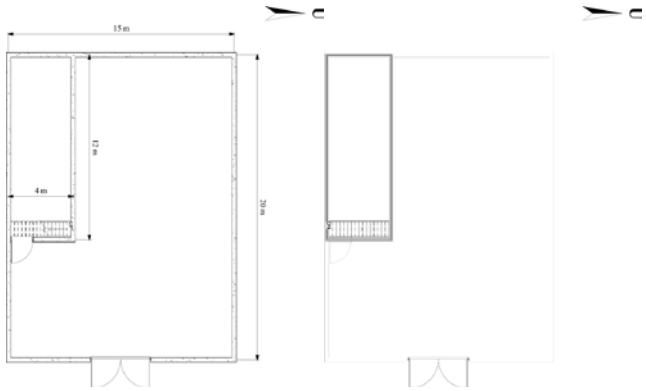


Figure 1. GATe Workshop Location Plan 1st and 2nd floor

Table 1. Department Space Requirement

No	Department	*Work Center*	Length (meter)	Wide (meter)	Number	*Work Center Area*	Worker	Worker Area	*Material Space*	Sub-Total	Total (x 150%)
1	Accessories	Electric Saw	0.3	0.3	1	0.09	1	0.62	2	2.71	4.07
2	*Assembly*	Welding	0.5	0.5	2	0.5	10	6.27	18.06	36.87	55.30
		Hand Grinding	0.3	0.3	2	0.18					
		Drilling Machine	0.3	0.3	2	0.18					
		Jig Chassis	4.2	1.6	1	6.72					
		Acrylic *Bending*	0.2	0.8	1	0.16					
		Shelf	4	1.2	1	4.8					
3	*Welding & Grinding*	Welding	0.5	0.5	1	0.25	4	2.50	2.6	8.62	12.94
		Hand Grinding	0.3	0.3	2	0.18					
		Bending	1.8	1.25	1	2.25					
		Assembly Table	1.4	0.6	1	0.84					
4	*Drilling*	Drilling	0.4	0.5	1	0.2	2	1.25	1	2.67	4.00
		Vise	0.36	0.6	1	0.216					
5	*Grinding*	Grinding Table	0.5	0.28	2	0.28	2	1.25	12	13.53	20.30
6	Electrical	Assembly Table	2.4	1.5	1	3.6	4	2.50	0	6.10	9.16
7	Oven	Painting Table	4.1	3.6	1	14.76	4	2.50	6.56	24.09	36.14
8	*Inventory Spare Part*	*Compressor Spray Gun*	0.3	0.3	2	0.18	4	2.50	0	23.14	34.72
		Electric Saw	0.3	0.3	1	0.09					
		Body Cover Shelf 1	2.4	1.2	1	2.88					
		Body Cover Shelf 2	4	1.2	1	4.8					
		Body Cover Shelf 3	4.8	1.2	1	5.76					
		Body Cover Shelf 4	6	1.2	1	7.2					
9	*Inventory* Material	Shelf	8	2	1	16	3	1.88	0	17.88	26.82
10	*Inventory* Waste	Inventory Room			1	0	4	2.50	5.4	7.90	11.86
		Finishing Body Cover			1	0					
	Total (square meter)									**143.56**	**215.35**

GATe car assembly activities are carried out in the middle area of the facility. There are machines, such as hand drills, welding equipment, and grinding machines placed around the assembly area.

The move in the manufacturing area is the main move that occurred at the GATe factory. To find out how the relationship between production departments depends on the number of movements that occur, a study was carried out regarding the number of movements between departments in the GATe production facility. Form-to-chart is displayed based on handling cost and movement frequency.

Table 2. *From to chart*

	Departments	1	2	3	4	5	6	7	8	9	10
1	Aksesoris		10938	3125	0	0	0	0	9375	3125	0
2	*Assembly*	10938		82813	7813	15625	9375	31250	37500	18750	0
3	*Welding & Grinding*	3125	82813		20313	53125	1563	0	10938	0	0
4	*Drilling*	0	7813	20313		0	3125	0	3125	0	0
5	*Grinding*	0	15625	53125	0		0	1563	0	0	0
6	Elektrikal	0	9375	1563	3125	0		0	4688	1563	0
7	Oven	0	31250	0	0	1563	0		0	0	0
8	*Inventory Spare Part*	9375	37500	10938	3125	0	4688	0		0	0
9	*Inventory* Material	3125	18750	0	0	0	1563	0	0		0
10	*Inventory* Material Sisa dan Barang Bekas	0	0	0	0	0	0	0	0	0	

	Departemen	1	2	3	4	5	6	7	8	9	10
1	Aksesoris		7	2	0	0	0	0	6	2	0
2	*Assembly*	7		53	5	10	6	20	24	12	0
3	*Welding & Grinding*	2	53		13	34	1	0	7	0	0
4	*Drilling*	0	5	13		0	2	0	2	0	0
5	*Grinding*	0	10	34	0		0	1	0	0	0
6	Elektrikal	0	6	1	2	0		0	3	1	0
7	Oven	0	20	0	0	1	0		0	0	0
8	*Inventory Spare Part*	6	24	7	2	0	3	0		0	0
9	*Inventory* Material	2	12	0	0	0	1	0	0		0
10	*Inventory* Material Sisa dan Barang Bekas	0	0	0	0	0	0	0	0	0	

From-to-chart is used to determine the relationship between production departments on the activity relationship diagram (ARC).

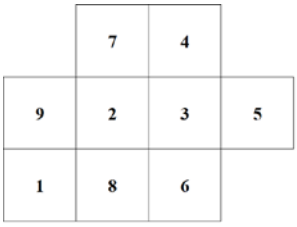
Table 3. ARC

Departments	1	2	3	4	5	6	7	8	9	10
1 Aksesoris		I/4	O/4	U	U	U	U	I/4	O/1	U
2 *Assembly*	I/1		A/1	I/1	E/1	I/1	A/1	A/1	E/1	U
3 *Welding & Grinding*	O/4	A/1		E/1	A/1	O/4	U	I/4	U	U
4 *Drilling*	U	I/1	E/1		U	U	U	O/4	U	U
5 *Grinding*	U	E/1	A/1	U		U	U	U	U	U
6 Elektrikal	U	I/1	O/4	U	U		U	O/4	O/1	U
7 Oven	U	A/1	U	U	U	U		U	U	U
8 *Inventory Spare Part*	I/4	A/1	I/4	O/4	U	O/4	U		U	U
9 *Inventory* Material	O/1	E/1	U	U	U	O/1	U	U		U
10 *Inventory* Material Sisa dan Barang Bekas	U	U	U	U	U	U	U	U	U	

Kedekatan	Rating	Keterangan
A	64	Mutlak berdekatan
E	16	Sangat penting untuk berdekatan
I	4	Penting untuk berdekatan
O	1	Kedekatan biasa
U	0	Tidak penting berdekatan
X	-1024	Tidak boleh berdekatan

Kode	Alasan
1	Kemudahan aliran material
2	Kemudahan pengawasan
3	Peralatan yang sama
4	Pekerja yang sama
5	Komunikasi
6	Kenyamanan

After creating *activity relationship diagram*, then creating the layout using *a dimensionless block diagram*



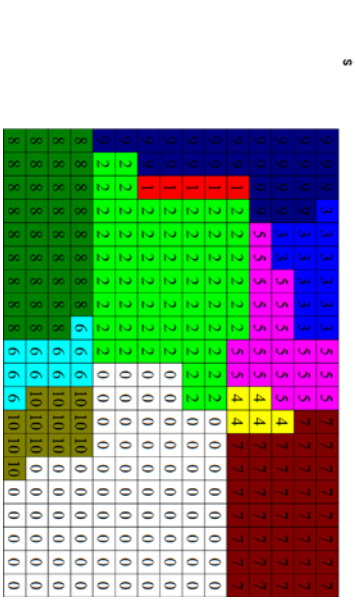
No	Departemen
1	Aksesoris
2	*Assembly*
3	*Welding & Grinding*
4	*Drilling*
5	*Grinding*
6	Elektrikal
7	Oven
8	*Inventory Spare Part*
9	*Inventory* Material
10	*Inventory* Material Sisa dan Barang Bekas

Figure 2. *Dimensionless Block Diagram*

Figure 3. Initial Layout

Alternative results using the CRAFT method, the production process is broken down into smaller activities and the relationships between these activities are examined to determine the

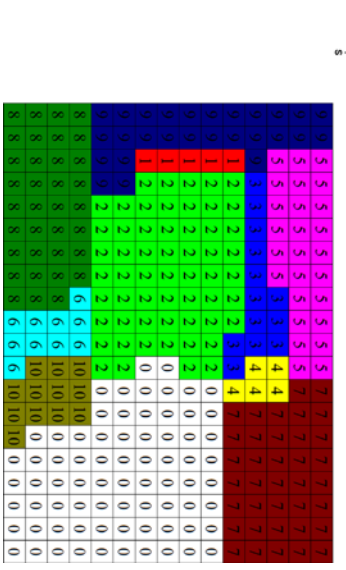
best distribution of resources. Closeness weights are then added to each department to get a Total Closeness Rating (TCR) figure.



No	Department	Color	Area-required	x-centroid	y-centroid
1	Aksesoris	1	5	6.5	17.5
2	*Assembly*	2	56	7.625	13.553572
3	*Welding & Grinding*	3	13	1.1923077	13.961538
4	*Drilling*	4	5	3.7	7.9000001
5	*Grinding*	5	21	2.5952382	10.976191
6	Elektrikal	6	10	13	10
7	Oven	7	37	2.4189188	3.7162163
8	*Inventory Spare Part*	8	35	13.042857	15.614285
9	*Inventory* Material	9	27	4.314815	18.537037
10	*Inventory* Material Sisa dan Barang Bekas	10	12	13	7.25

Figure 4. Initial Layout Mapping

Based on the initial layout, a material handling cost value of IDR 4,265,989.00 was obtained using the add-in from Microsoft Excel. Next, the first iteration is carried out to get a layout with optimal values.



No	Department	Color	Area-required	x-centroid	y-centroid
1	Aksesoris	1	5	6.5	17.5
2	*Assembly*	2	56	7.5	12.6228065
3	*Welding & Grinding*	3	13	3.42307687	11.8076925
4	*Drilling*	4	5	3.29999995	7.9000001
5	*Grinding*	5	21	1.34615386	13.4615383
6	Elektrikal	6	10	13	10
7	Oven	7	37	2.41891885	3.71621633
8	*Inventory Spare Part*	8	35	13.0428572	15.6142855
9	*Inventory* Material	9	27	6.09259272	18.6481476
10	*Inventory* Material Sisa dan Barang Bekas	10	12	13	7.25

Figure 5. Iteration-1

Based on the layout results of the 1st iteration, using the add-in from Microsoft Excel, a material handling cost value of IDR 3,680,876.00 was obtained.

From the analysis results, the value from the 1st iteration is the optimal value, so the optimal value for material handling costs from the CRAFT Workshop GATe method is IDR 3,680,876.00.

After getting an alternative layout, it is necessary to calculate the layout's Total Closeness Rating (TCR) value. Calculation of alternative scores from the CRAFT method is as follows.

Table 4. TCR Value

Adjacents Dept	*Proximity Ratings*	*Score*
(1, 2)	I	4
(1, 9)	O	1
(2, 3)	A	64
(2, 6)	I	4
(2, 7)	A	64
(2, 8)	A	64
(2, 9)	E	16
(3, 4)	E	16
(3, 5)	A	64
(4, 7)	U	0
(5, 8)	U	0
(6, 8)	O	1
Total		298

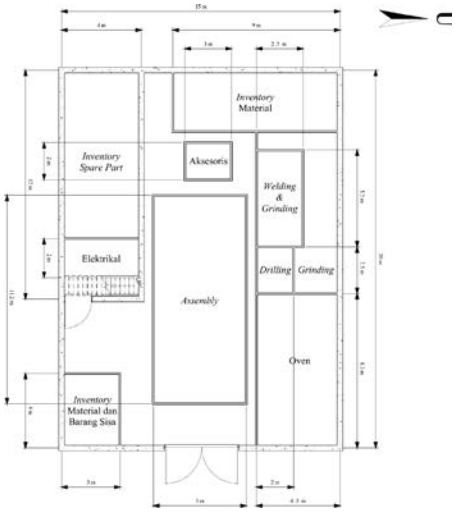


Figure 6. Alternative Workshop GATe Layout

The layout results of the CRAFT algorithm are shown in Figure 6. after modification based on the shape of the GATe production facility.

After getting an alternative workshop layout using the CRAFT method, the material displacement load value was calculated using the Euclidean method which can be seen in Figure 7.

Figure 7. Distance Calculation
Euclidean in CRAFT Method Results Layout

Table 5 *From-to-chart* Moving Distance

	Departemen	1	2	3	4	5	6	7	8	9	10
1	Aksesoris		4.98	6.47	10.12	6.55	9.92	14.38	6.81	1.22	12.14
2	*Assembly*			4.16	6.32	6.21	6.09	10.25	6.30	6.19	7.69
3	*Welding & Grinding*				3.91	2.65	9.75	8.15	10.35	7.34	10.61
4	*Drilling*					5.89	9.92	4.28	12.43	11.11	9.72
5	*Grinding*						12.16	9.80	11.89	7.03	13.21
6	Elektrikal							12.31	5.61	11.07	2.75
7	Oven								15.95	15.38	11.16
8	*Inventory Spare Part*									7.58	8.36
9	*Inventory* Material										13.33
10	*Inventory* Material Sisa dan Barang Bekas										
	389.49 meter										

The total displacement load calculated using the CRAFT method obtained a value of 1177.8 m.

Conclusion

After carrying out calculations and analysis using the CRAFT method, a total closeness rating was obtained of 298. The material handling cost value resulting from the CRAFT method iteration was smaller than the initial layout. The material handling value for the CRAFT method is IDR

3,680,876.00, while the initial layout is IDR 4,265,989.00. Meanwhile, the displacement load is 1177.8802 m.

THANK-YOU NOTE

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