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Improving Multi-Floor Factory Facilities Layout Using CRAFT Algorithm Method in UMKM Aneka Songkok Jombang

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Abstract— UMKM Aneka Songkok is a multi-floor building consisting of several departments. The problem that occurs is that the placement of departments is considered less than optimal and does not correspond to the production process sequence, resulting in backtracking in the material flow process. This study aims to improve the layout design to make the facility layout more effective and efficient, thereby making the production process flow more organized and minimizing material movement distances between departments. The method used is the CRAFT algorithm method, a computer program used to find an optimal design by gradually improving the layout. The results of the study show that the distance traveled for one production cycle in the initial layout is 325 m, while in the proposed layout it is 215.65 m, with a distance difference of 109.35 m, resulting in a reduction of 33.65%. The distance traveled for material movement in one day of production in the initial layout was 1,270.5 meters, while in the proposed layout it was 883.2 meters, with a distance difference of 387.3 meters, resulting in a reduction percentage of 30.48%. Therefore, it can be concluded that the proposed layout successfully minimizes material movement distance.

Keywords— Craft Algorithm, Facility Layout Optimization, Multi-floor, Production Effectiveness.

I. INTRODUCTION

Layout is an integrated plan for the flow of product components from departments that play an important role in supporting the production process [1]. A common problem with layout is that the production floor is not well organised due to the distance between one machine and another being irregular [2]. UMKM Aneka Songkok has been producing various types of songkok since 1997 and has several production floors, including a production floor built with a multi-floor concept.

Based on observations and interviews, it was found that the owner faces issues with the placement of departments, which are deemed less than optimal and not aligned with the production process sequence, leading to backtracking in the material flow process. The frequency of back-and-forth movements between departments results in a total material movement distance of 1,270.5 metres per day. For one production cycle, the total distance travelled is 325 metres, taking 37.5 minutes. This material transfer process is mostly done

manually, with employees lifting materials from one departments to another, causing workers to experience excessive fatigue due to wasted movements.

To address these issues, this study applies the Craft Algorithm Method. CRAFT (Computerized Rellative Allocation of Facility Technique) is an example of a heuristic engineering program based on quadratic assignment interpretation that uses basic criteria to minimise material movement [3]. Layout improvements are carried out gradually by exchanging locations between departments or work units within a factory [4]. Through this research, it is hoped that it will be possible to redesign the layout of facilities that are effective and efficient so that the production process flow pattern becomes more orderly and minimizes the distance of material movement between departments.

II. RELATED WORKS

A. Facility Layout

Layout design is a vital element in business because it can affect a company's efficiency in the long term [5][6]. Planning and arranging the optimal layout of facilities is key to achieving productivity, efficiency, and effectiveness in a business because it creates a smooth production flow, reduces the distance materials need to be moved, and reduces transportation costs [7]. A good production facility layout should not have any backflow, should have a minimum transfer frequency, and should not have excessive queues [8]. The basic principles of factory layout planning are that all production process factors are integrated, minimising the distance goods are moved, and streamlining the workflow [9]. Layout issues are not always layout issues for new facilities, but also about rearranging existing layouts or changing parts of specific equipment [10].

B. Work Map

A work map is a tool that systematically and clearly illustrates work activities in analysing work processes from start to finish [11]. An Operation Process Chart (OPC) is a diagram that illustrates the steps in the process that raw materials undergo to become finished products [12]. This map also contains information needed to analyse working hours, materials, locations, tools and machinery used [13]. A Flow Process Chart (FPC) is a series of steps from raw materials to finished products that helps us understand how production processes work in a factory. An FPC shows all basic activities, including transportation, waiting, and storage, while an OPC is limited to operations and inspections only. This means that an FPC can analyse each component that is processed more thoroughly [14]. A process flow diagram is a scaled representation of the layout of floors and buildings, showing the location of all activities that take place [15].

C. Activity Relationship Chart

The ARC table contains the relationship levels that exist in each facility, which will facilitate the process of redesigning the layout in accordance with the results of the ARC table. Input is carried out by identifying the level of necessity of one facility with another during the production process from start to finish [16]. After completing the ARC, the next step is to summarise the results in a worksheet to make it easier for designers to understand the level of connection between one activity centre or facility and another [17].

D. Activity Relationship Diagram

ARD is an advanced form of worksheet and ARC. Activity Relationship Diagram (ARD) is a diagram of the relationship between activities based on priority level of proximity, so that minimum handling costs are expected [18]. Activity relationship diagrams are used to combine the degree of activity relationships and material flow, with the degree of proximity between facilities indicated by letter codes, lines, and colours. This visualisation also facilitates observation when deciding where to go [19].

E. Form To Chart

From To Chart is a conventional technique that is commonly used in factory planning and material handling in a production process. This technique is advantageous for conditions where many items flow through an area [20]. The numbers on the From To Chart will show the total weight of the load moved, the volume, or a combination of both [21].

F. Craft Algorithm

CRAFT is a development-type algorithm, an improvement made to the program to find the optimal plan by performing a gradual improvement process and requiring the layout of the actual factory or the layout created by other algorithms. In department exchanges based on the CRAFT method, three conditions must be met, namely similarity of boundaries, similarity of size, and similarity of both boundaries in the three departments [22]. The main objective of the CRAFT algorithm is to minimise total costs with the following objective function:

$$TC = \sum Dij \times Wij \times Cij \qquad (1)$$

G. Software Excel Add-ins

Excel Add-ins are additional programs that can enhance Excel functionality. The analysis steps performed using the CRAFT method in Microsoft Excel Add-Ins begin with determining the number of departments to be analysed and identifying departments that cannot be moved (fixed points). Next, enter the area of each department. The first initial data tables to be filled are the Layout Data table, Facility Information table, Department Information table, Flow Matrix table, and Cost Matrix table [23].

H. Distance Measurement

The process of moving materials is classified as a non-productive activity, so minimising distance is necessary to achieve an effective and efficient layout. The distance measurements that can be used for facility layout design are Euclidean and rectilinear distance measurements. Rectilinear distance, also known as Manhattan distance, is the distance calculated in a straight line along a path, referred to as Manhattan distance. Rectilinear distance measurement is one of the most commonly used measurements because it is easy to calculate, easy to understand, and applicable to real-world problems, such as determining the distance between buildings on a university campus. Rectilinear distance measurement can be expressed in the following equation [2]:

$$dij = |xi - xj| + |yi - yj| \qquad (2)$$

III. METHOD

A. Data Collection Methods

The data required for this study are primary data and secondary data. The explanation of these data is as follows:

1. Primary Data

Primary data is data obtained directly from the field, such as through observation and interviews with the owner of UMKM Aneka Songkok Jombang.

a. Observation

Observation is the direct collection of data in the field to identify problems with the layout of machinery and facilities used. The data obtained during observation includes initial layout data, departments area data, and data on the distance between departments.

b. Interview

The interview was conducted by asking several questions that had been prepared for the interview in order to obtain valid information and data from the relevant sources and to understand the process. The data obtained during the interview was in the form of production process flow data.

2. Secondary Data

Secondary data is data obtained through data that has been researched and collected by other parties related to this issue, such as books or research journals. This data is used by the author as a reference to complete this research.

B. Data Processing Method

Once the required data has been collected, the next step is to process the data. Data processing aims to resolve and discuss the problems being analyzed. Steps taken data processing are:

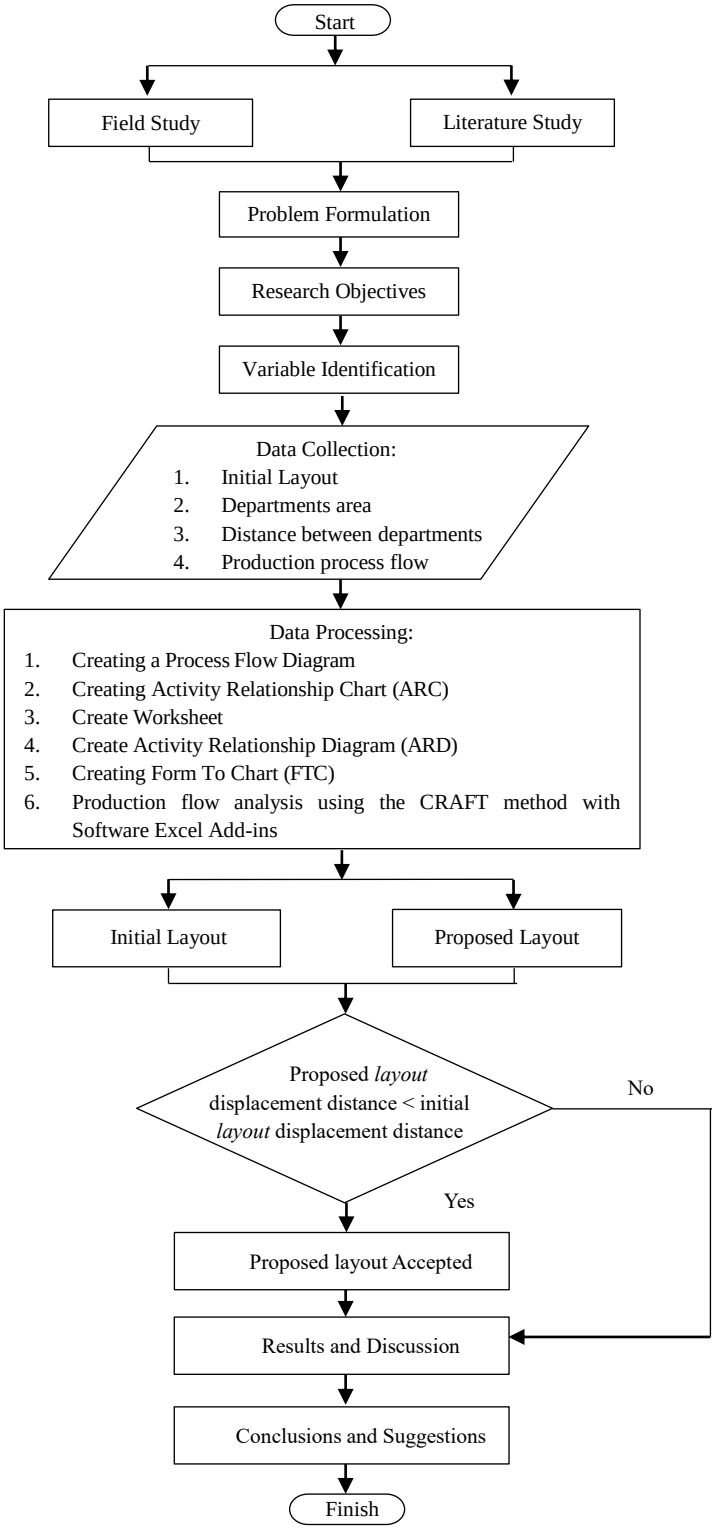


Figure 1. Research Flow

IV. RESULT AND DISCUSSION

A. Data Collection

1) Initial Layout UMKM Aneka Songkok

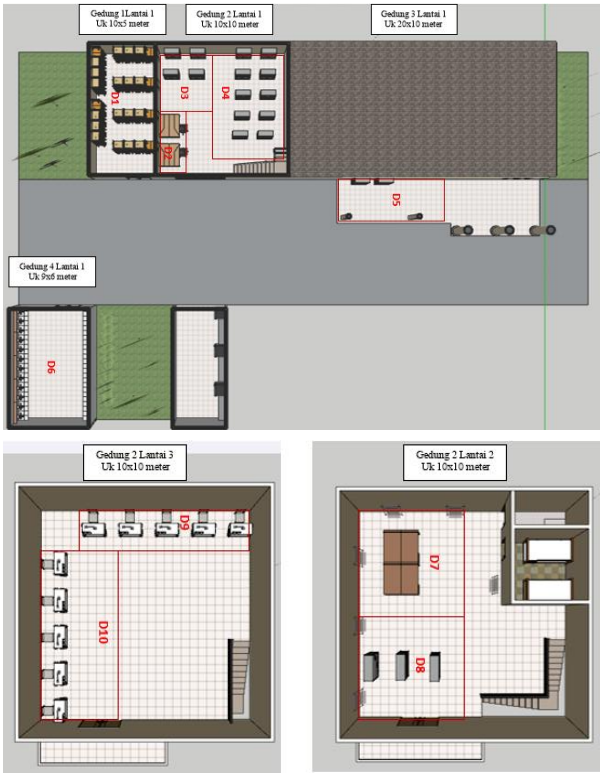


Figure 2. Initial Layout UMKM Aneka Songkok

Based on Figure 2, it can be seen that UMKM Aneka Songkok Jombang has 5 buildings with a total floor area of 440 meters, and one of the buildings is constructed with a multi-floor concept. The number of departments at the UMKM Aneka Songkok Jombang is 10 departments, namely finished goods warehouse 1, office, raw material warehouse, finished goods warehouse 2, packing, embroidery, cutting, finished goods warehouse 3, sewing 1, and sewing 2.

2) Departments Area UMKM Aneka Songkok

The size of the departments at UMKM Aneka Songkok can be seen in the following table:

Table 1. Departments Area UMKM Aneka Songkok

No.	Name	Floor	Code	length x width (m)	Area (m)
1.	Finished Material Warehouse 1	1	D1	10 × 5	50
2.	Songkok Design	1	D2	5 × 2	10
3.	Raw Material Warehouse	1	D3	5 × 4	20
4.	Finished Material Warehouse 2	1	D4	9 × 6	54
5.	Packing	1	D5	10 × 3	30
6.	Embroidery	1	D6	9 × 6	54
7.	Cutting	2	D7	5 × 5	25
8.	Finished Material Warehouse 3	2	D8	5 × 5	25
9.	Sewing 1	3	D9	8 × 2	16
10.	Sewing 2	3	D10	8 × 4	32
	Total				316

Table 1 shows total area of the 10 departments at UMKM Aneka Songkok Jombang is 316 m, the building area of UMKM Aneka Songkok Jombang still has a surplus of 124 m.

3) Coordinates Point of Initial Layout

The coordinates for each department were obtained using Autocad software. The distances were calculated using the rectilinear formula.

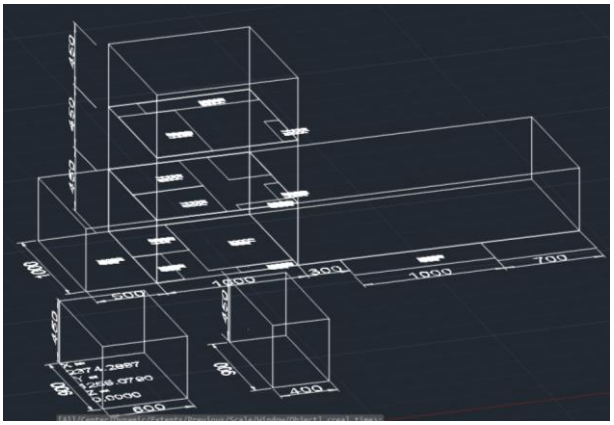


Figure 3. Initial Layout 3D

The coordinates for the initial layout of UMKM Aneka Songkok can be seen in the following table:

Table 2. Coordinates Point of Initial Layout

Code	Point Coordinates (m)		
	X	Y	Z
D1	29,24	34,06	0
D2	32,74	31,56	0
D3	33,74	36,56	0
D4	38,74	34,56	0
D5	49,74	27,56	0
D6	23,74	12,56	0
D7	34,24	36,56	4,50
D8	34,24	31,56	4,50
D9	37,74	38,06	9,00
D10	33,74	33,06	9,00

Table 3. Coordinates Point of Stairs Initial Layout

Name	Point Coordinates (m)		
	X	Y	Z
1st Floor Stairs	39,74	29,56	0
2nd Floor Stairs (1)	39,74	29,56	4,5
2nd Floor Stairs (2)	41,24	31,06	4,5
3rd Floor Stairs	41,24	31,06	9

4) Distance Between Departments Initial Layout

After obtaining the coordinates for each departments, the distance between each departments can be calculated using the rectilinear formula. Example of calculating the distance between departments D3 on the 1st floor to D9 on the 2nd floor:

- Point 1 (D3 Floor 1- 1st Floor Stairs)

  $dij = |xi - xj| + |yi - yj| + |zi - zj|$

  $= |33,74 – 39,74| + |36,56 – 29,56| + |0,00 – 0,00|$

  $= 13$

- Point 2 (1st Floor Stairs - 2nd Floor Stairs (2))

  $dij = |xi – xj| + |yi - yj| + |zi - zj|$

  $= |39,74 – 41,24| + |29,56 – 31,06| + |0,00 – 4,50|$

  $= 7,5$

- Point 3 (2nd Floor Stairs (2) - D9 Floor 2)

  dij = |xi – xj| + |yi - yj|+ |zi - zj|

  = |41,24 – 14,21| + |31,06 – 21,52|+ |4,50 – 4,50|

  = 12,5

- Total Distance = Point 1 + Point 2 + Point 3

  = 13 + 7,5 + 12,5

  = 33

Based on calculations using the rectilinear formula, the distance between each departments is obtained, as shown in the following table:

Table 4. Distance Between Departments Initial Layout

No	Start Departement	Departement Objectives	Average Frequency/Day	Displacement Distance (m)	Displacement Moment (m)
1	D3 1st Floor	D7 2nd Floor	2	33	66
2	D7 2nd Floor	D9 3rd Floor	6	30,5	183
3	D9 3rd Floor	D6 1st Floor	4	61,5	246
4	D2 1st Floor	D6 1st Floor	1	28	112
5	D6 1st Floor	D10 3rd Floor	4	60,5	363
6	D10 3rd Floor	D5 1st Floor	6	39,5	39,5
7	D5 1st Floor	D1 1st Floor	5	27	216
8	D5 1st Floor	D4 1st Floor	5	18	18
9	D5 1st Floor	D8 2nd Floor	3	27	27
		TOTAL		325	1270,5

B. Data Processing

1) Process Flow Diagram UMKM Aneka Songkok

The depiction of material flow that takes place from the beginning to the end of the process is done on the layout drawing of the production facility. The following is a flow chart of the production floor at UMKM Aneka Songkok Jombang:

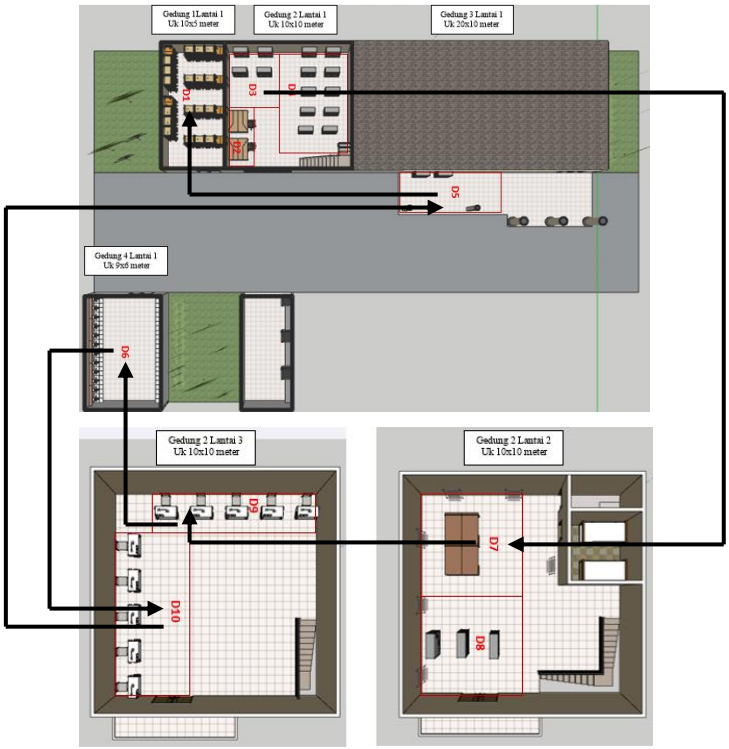
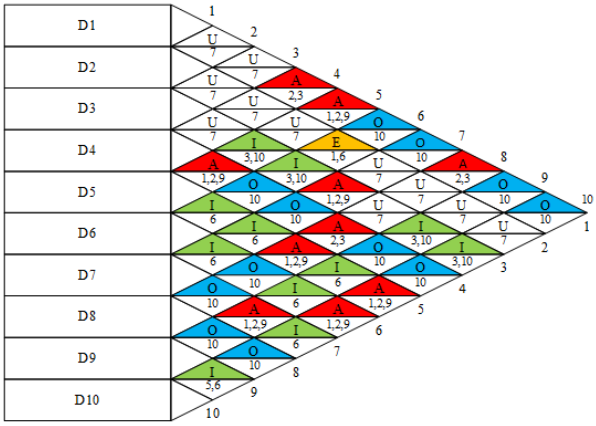


Figure 4. Process Flow Diagram UMKM Aneka Songkok

2) Activity Relationship Chart (ARC) UMKM Aneka Songkok

Activity Relationship Chart illustrates the relationship of closeness of each department. The following is the ARC from UMKM Aneka Songkok Jombang:



Value	*Closeness*
A	Absolutely necessary
E	Very necessary
I	Need
O	Regular
U	Not necessary
X	Unwanted

Degree of Proximity Value	
Reason Code	Reason Description
1	Process Flow Sequence
2	Smooth Material Flow
3	Make Moving Goods Easy
4	Using the Same Room
5	Using the Same Tool
6	Facilitate Supervision
7	No Employment Relationship
8	Safety and Comfort
9	High Frequency of Use
10	Low Frequency of Use

Figure 5. Activity Relationship Chart UMKM Aneka Songkok

3) Worksheet UMKM Aneka Songkok

Worksheet are intended to facilitate understanding of the relationships between activities. The following is a worksheet from the ARC diagram:

Table 5. Worksheet UMKM Aneka Songkok

Worksheet						
Code	**A**	**E**	**I**	**O**	**U**	**X**
D1	4,5,8	-	-	6,7,9,10	2,3	-
D2	-	6	-	-	1,2,3,4,5,7,8,9,10	-
D3	7		5,6,9,10	-	1,2,4,8	-
D4	1,5,8	-	-	6,7,9,10	2,3	-
D5	1,4,8,10	-	3,6,7,9	-	2	-
D6	10	2	3,5,7,9	1,4,8	-	-
D7	3,9	-	5,6,10	1,4,8	2	-
D8	1,4,5	-	-	6,7,9,10	2,3	-
D9	7	-	3,5,6,9	1,4,8	2	-
D10	5,6	-	3,7,9	1,4,8	2	-
Total	**20**	**2**	**22**	**24**	**27**	**0**
Overall				**95**		

4) Activity Relationship Diagram (ARD) UMKM Aneka Songkok

The following is the ARD created based on the level of closeness obtained from the ARC table that has been created:

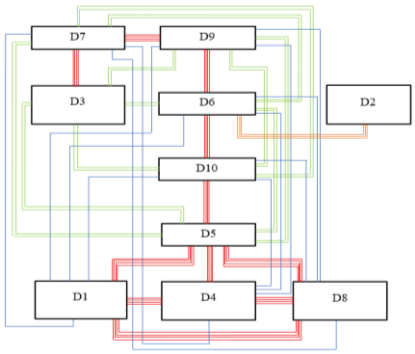


Figure 6. Activity Relationship Diagram UMKM Aneka Songkok

5) Form To Chart Initial Layout

In the initial From To Chart layout, there are 10 departments used. The following is a From To Chart based on the distance between departments in the songkok production process at UMKM Aneka Songkok Jombang:

Table 1. Form To Chart Initial Layout

Form To Chart										
Form - To	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
D1										
D2						28				
D3							33			
D4										
D5	27			18				27		
D6										60,5
D7									30,5	
D8										
D9						61,5				
D10					39,5					

6) CRAFT Algorithm Initial Layout

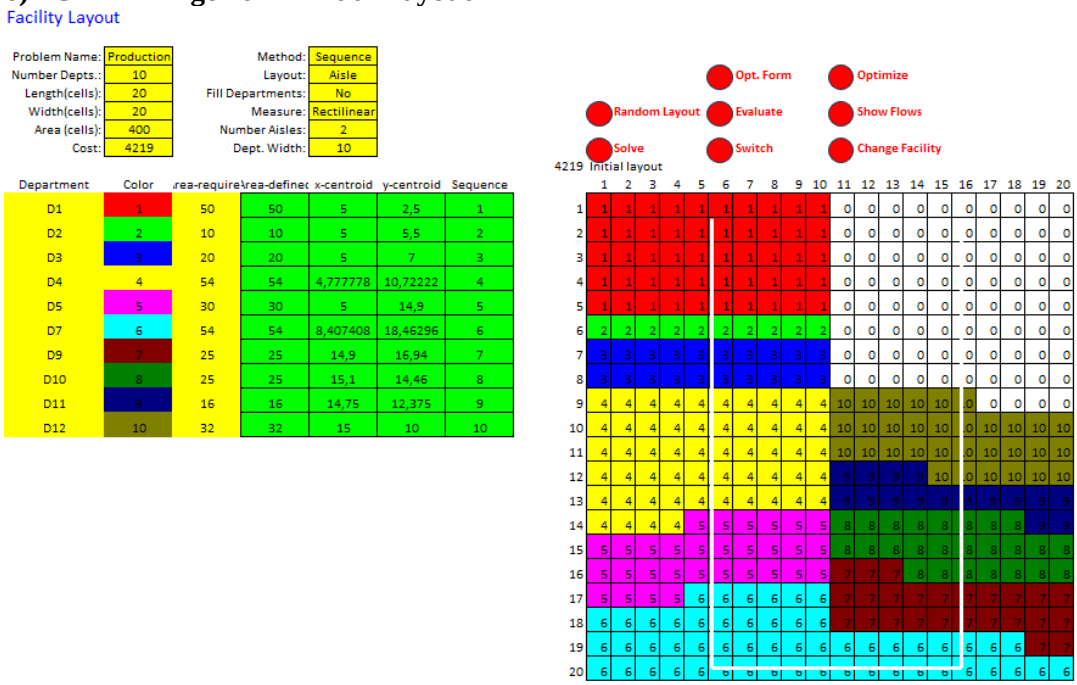


Figure 7. CRAFT Algorithm Initial Layout

In Figure 7, shows the initial layout design in the Excel add-ins. There are 10 departments that will be relocated, using an area measuring 20×20 metres. Different colours are used to represent each department.

7) CRAFT Algorithm Proposed Layout

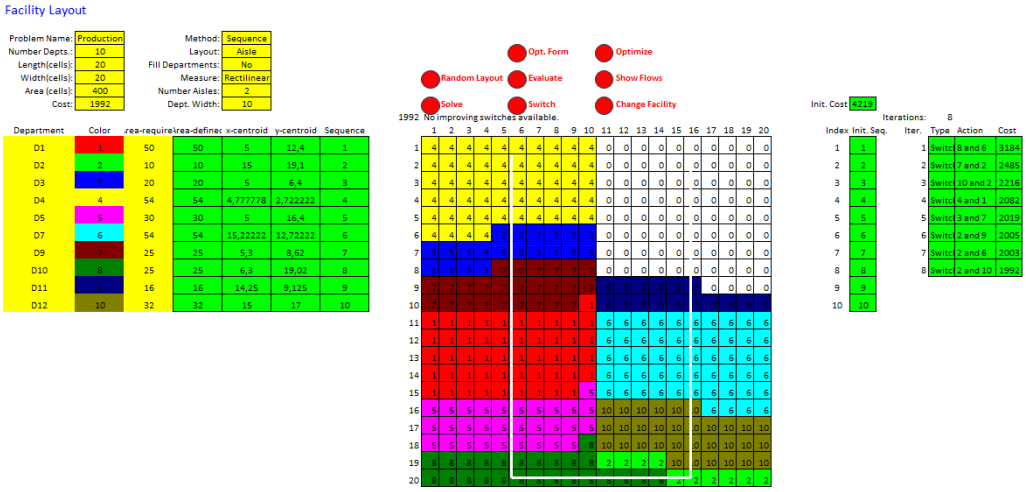


Figure 8. CRAFT Algorithm Proposed Layout

Data processing using the CRAFT algorithm resulted in several iterations, including Improve by switching departments 8 and 6, Improve by switching departments 7 and 2, Improve by switching departments 10 and 2, Improve by switching departments 4 and 1, Improve by switching departments 3 and 7, Improve by switching departments 2 and 9, Improve by switching departments 2 and department 6, and Improve by switching departments 2 and 10. Based on the results obtained from the CRAFT algorithm, the alternative selected in this study is all the iterations generated. This was chosen based on analysis using ARC and the conditions of department size and available building space.

8) Proposed Layout UMKM Aneka Songkok

After obtaining the output results from the CRAFT Algorithm regarding which alternatives were selected, the proposed improvement layout was then redrawn as follows:

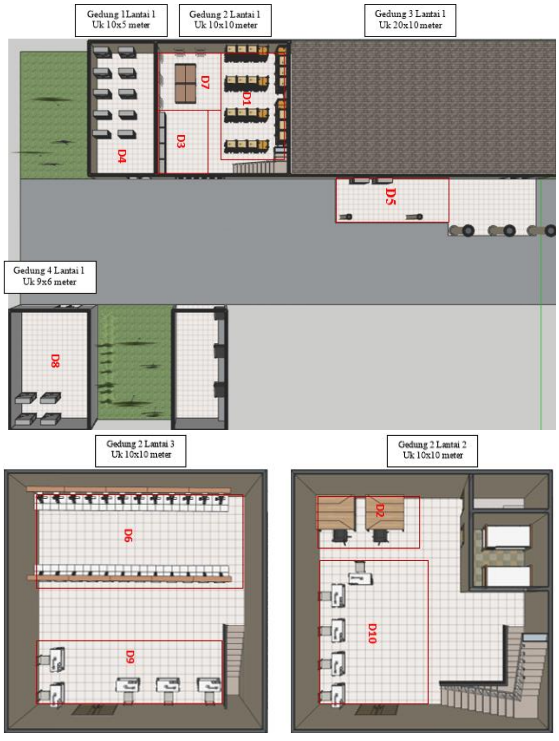


Figure 9. Proposed Layout UMKM Aneka Songkok

9) Coordinate Point of Proposed Layout

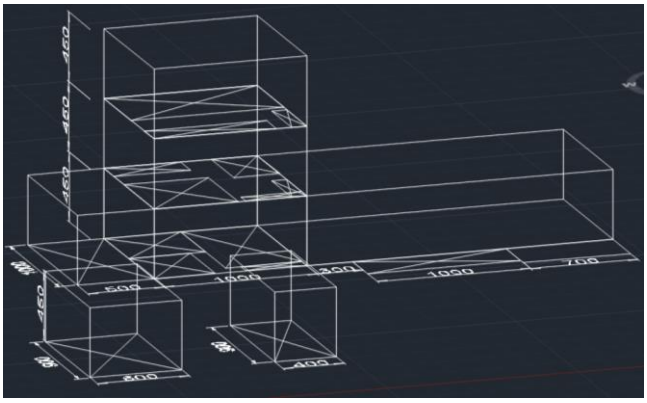


Figure 10. Proposed Layout 3D

The coordinates of the proposed layout for UMKM Aneka Songkok can be seen in the following table:

Table 7. Coordinat Point of Proposed Layout

Code	Point Coordinates (m)		
	X	Y	Z
D1	39,24	34,56	0
D2	34,24	38,06	4,5
D3	33,74	31,56	0
D4	29,24	34,06	0
D5	49,74	27,56	0
D6	36,74	36,36	9
D7	34,24	36,56	0
D8	23,74	12,56	0
D9	35,74	30,06	9
D10	34,49	32,06	4,5

Table 8. Coordinates Point of Stairs Proposed Layout

Name	Point Coordinates (m)		
	X	Y	Z
1st Floor Stairs	39,74	29,56	0
2nd Floor Stairs (1)	39,74	29,56	4,5
2nd Floor Stairs (2)	41,24	31,06	4,5
3rd Floor Stairs	41,24	31,06	9

10) Distance Between Departments Proposed Layout

Based on calculations using the rectilinear formula, the distance between each departments is obtained, as shown in the following table:

Table 9. Distance Between Department Proposed Layout

No	Start Departement	Departement Objectives	Average Frequency/Day	Displacement Distance (m)	Displacement Moment (m)
1	D3 1st Floor	D7 1st Floor	2	5,5	11
2	D7 1st Floor	D9 3rd Floor	6	37	222
3	D9 3rd Floor	D6 3rd Floor	4	7,3	29,2
4	D2 2nd Floor	D6 3rd Floor	1	31,3	31,3
5	D6 3rd Floor	D10 2nd Floor	4	25,05	100,2
6	D10 2nd Floor	D5 1st Floor	6	24	144
7	D5 1st Floor	D1 1st Floor	5	17,5	87,5
8	D5 1st Floor	D4 1st Floor	5	27	135

9	D5 1st Floor	D8 1st Floor	3	41	123
		TOTAL		215,65	883,2

11) Form To Chart Proposed Layout

In the proposed From To Chart layout, there are 10 departments used. The following is a From To Chart based on the distance between departments in the songkok production process at UMKM Aneka Songkok Jombang:

Table 10. Form To Chart Proposed Layout

Form To Chart										
Form - To	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
D1										
D2						31,3				
D3							5,5			
D4										
D5	17,5			27				41		
D6										25,05
D7									37	
D8										
D9						7,3				
D10					24					

12) Evaluation of Proposed Layout Results

After obtaining the distance values between departments in the proposed layout using the CRAFT algorithm, a recapitulation of the comparison results between the initial layout distance and the proposed layout distance was carried out. This served to determine the level of efficiency achieved. The following is a table summarizing the distance of movement at UMKM Aneka Songkok Jombang before and after the change:

Table 11. Total and Difference of One Round Distance

No	Layout	Total Distance (m)	Difference in Total Distance (m)	Percentage decrease (%)
1.	Initial Layout	325	-	-
2.	Proposed Layout	215,65	109,35	33,65%

Table 12. Total and Difference in Distance Moved per Day

No	Layout	Total Distance (m)	Difference in Total Distance (m)	Percentage decrease (%)
1.	Initial Layout	1270,5	-	-
2.	Proposed Layout	883,2	387,3	30,48%

C. Discussion

With the help of the craft algorithm method, a new layout design has been proposed for the UMKM Aneka Songkok Jombang. As a comparison, in the initial layout, the total distance travelled for one production cycle was 325 m and the total movement distance in one day was 1270.5 m. In the proposed layout, there is a reduction in material movement distance, resulting in a total distance of 215.65 m for one production cycle and a daily movement distance of 883.2 m. The percentage The percentage reduction in material movement distance for one production cycle is 33.65%, and the material movement time per day is 30.48%.

The calculation results prove that the layout improvements implemented are efficient as they minimise material handling distances between departments. Smooth material flow

automatically reduces process time in the production area significantly, thereby increasing
productivity levels. The implementation of the new layout at UMKM Aneka Songkok can also improve workplace safety because workers no longer experience unnecessary movements that cause excessive fatigue. With shorter travel distances, operators no longer need to perform long material handling movements, allowing them to focus on their work and increase production output. This demonstrates that the proposed layout successfully reduces material movement distances and the layout design can be considered successful.

V. CONCLUSION

The redesign of the layout of facilities at UMKM Aneka Songkok Jombang was carried out using the CRAFT (Computerized Relative Allocation of Facilities Techniques) algorithm method. Based on the data processing results, it was found that 8 iterations were selected for layout exchange, namely between finished goods warehouse 3 and embroidery, cutting with songkok design, sewing 2 with songkok design, finished goods warehouse 4 with finished goods warehouse 1, raw materials warehouse with cutting, songkok design with sewing 1, songkok design with embroidery, and songkok design with sewing 2. Based on the data processing results, a comparison of the material movement distances between the initial layout and the proposed layout was obtained. The distance traveled for one production cycle in the initial layout was 325 m, while in the proposed layout it was 215.65 m, with a distance difference of 109.35 m, resulting in a reduction percentage of 33.65%. The distance traveled for material movement in one day of production in the initial layout is 1,270.5 m, while in the proposed layout it is 883.2 m, with a distance difference of 387.3 m, resulting in a reduction percentage of 30.48%. It is hoped that this research can be used or developed as the main idea for further research related to facility layout improvements, and further research is needed to consider the Material Handling Costs (OMH) and increase production output and is expected to consider using more than one facility layout design method in order to find out the results and comparison between methods.

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