APPLICATION OF LEAN LAYOUT PLANNING TO REDUCE WASTE IN A SLIPPERS MANUFACTURING: A CASE STUDY

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ABSTRACT: Lean principles encourage every company to reduce waste in all aspects to achieve optimal productivity. One application area in the domain is layout planning, which can help reduce interdepartmental distance and enhance throughput. This research is based on Azka Pratama, which is a small and medium-sized enterprise (SME) producing sponge slippers in Yogyakarta, Indonesia. The company faces material handling challenges between departments leading to higher production time and low throughput. This study intends to improve the layout of the facility so as material handling time may be reduced. In the context of this research, facility layout redesigning employs the activity relationship chart (ARC) and computerized relative allocation facilities technique (CRAFT) methods after which, simulations were used to analyze the proposed layouts. The results indicate that the CRAFT technique reduced the distance by 53.76% and material handling time by 37.13%, leading to a throughput enhancement of 2.39%. In comparison, the ARC method leads to 34.29% and 25.52% reduction in distance and material handling time, respectively, thereby leading a throughput increase of 3.75%. For implementation, the new layout resulting from CRAFT methods is recommended because the renovation cost is cheaper than ARC methods with the result is closer to ARC.

KEYWORDS: *Re-layout Planning; Waste; ARC; CRAFT; Simulation*

1.0 INTRODUCTION

Assessment of managerial decisions is often carried out using operations research with a lean approach. The lean approach teaches the company to continuous improvement with the DMAIC (Define, Measure, Analyze, Improve and Control) method. For instance, a production area can be considered optimal if there is minimum waste of time in material transport. In the context of production facilities, the layout has a crucial role in determining operational effectiveness and efficiency, thereby governing success [1]. Enterprises require that all resources should be utilised efficiently to produce goods and services since high efficiency leads to better cost and production time [2]. Azka Pratama is an SME that manufactures snug and high-quality sponge slippers, which are often used in hotel and souvenirs. The layout has a significant effect on production volumes when material flow is not optimal and product demand increases. The materials must traverse 1,437.90 m for 249 seconds per unit, thereby indicating that 22.71% of the total production time is consumed for material movement. Hence, the layout must be optimised.

Lean principle is very suitable to be applied to optimize work space because it is proven to reduce production lead time by analysing non-added value [3],[4]. There are many techniques that can be used to optimize work space and productivity for the improvement phase and not only related to layout issues, but also capacity planning [5] and product routing [6]. The ARC technique is widely used during qualitative evaluations and may have subjective aspects. This technique can design work stations and locations that are suitable for a series of activities [1]. The CRAFT technique consists of changing the location of the activity with reference to the initial layout to determine the optimized material flow, in an iterative way to produce the final layout for minimum cost [7]. Arena software is a simulation software based on the SIMAN (Simulation Modeling and Analysis) block with a few additional modules, apart from that it also offers structure visualization, parameter modeling, input-output analysis, control and animation systems, and output reports [8]. Sembiring et al. [9] have conducted research using CRAFT techniques and WinQSB V2.0 software, where the research suggests reorganizing facilities according to the material flow. Re-layout the facility using From-To-Chart technique while using ARC technique to solve the problem, successfully reducing material movement [10]. Haryanto et al. [11] has taken advantage of the integrated of SLP-CRAFT form and graph method and was able to optimize material handling costs.

Combination of CRAFT algorithm and CORELAP (Computerized Relationship Layout Planning) to address the facility-specific challenges at PT Peace Industrial Packaging, effectively reduce total distance reduction of 60.21% [12]. Research using ARC and CRAFT methods with WinQSB software to solve layout problems was successfully carried out, with better results at a reasonable cost [2]. Faishal et al. employed MULTIPLE techniques and used the simulation approach using ProModel 6.0 software to address layout-specific challenges in the context of the food industry [13]. the ARC and ARD techniques successfully reduce material handling distance by address layout-specific challenges at PT GMF Aero Asia Tbk one of the biggest aircraft maintenance companies, by optimizing the distance and costs [14]. Suhardi et al. studied a combination of the Systematic Layout Planning (SLP) and ergonomics approach to minimize total material handling cost by 22.92% [15]. Hidayat et al. [16] redesigning facility layout using quantitative and qualitative methods. Their work resulted in a 13.98% reduction in total distance. Felecia, et al. [17] has changed the layout of the library for aligned native digital generation to meet the needs of digitally oriented native generation. Layout improvements to minimize material handling costs on the production floor can be successfully carried out with a combination of several systematic Layout Planning methods such as the example on the furniture production floor and of course produce different results [18],[19]. Hence, the objective of this study is optimised the layout using the ARC and CRAFT techniques along with simulations performed using Arena software to assess changes in production. A good layout will increase productivity and of course prevent quality problems, which is related to customer satisfaction [20],[21].

2.0 METHODOLOGY

This study aims to improve the facility's layout to reduce material handling time in the production line of the slipper factory. To study the objective of the research, the following research methodology was adopted, which is depicted in Figure 1. The uniqueness of this study is the use of a complex approach methods both in visualizing spatial relationships, emphasizing quantitative optimization and strengthening with simulations before the recommendations are implemented to minimize shipping time [22].

Preliminary study conducted as initial observation by survey at company and discussion with the owner to get the real problem. After all the problems are identified, the necessary data is taken directly at the company by measuring directly and surveying all employees. Then process the data that has been obtained according to the need to make layout improvements. After calculating from to chart by transforming primary data into a form suitable for maps, proceed with creating a matrix in accordance with the calculated activity. Then ARC analysis is carried out to produce a layout by considering the order of material flow and its relevance to making the layout following the order. The CRAFT method is carried out in the WINQSB V3.0 software with several iterations with data input from the ARC method output to create a minimum material handling cost (MHC) layout. Then a simulation model is created to evaluate production rates for alternative layouts, thereby creating an understanding of the increase in production after implementation.

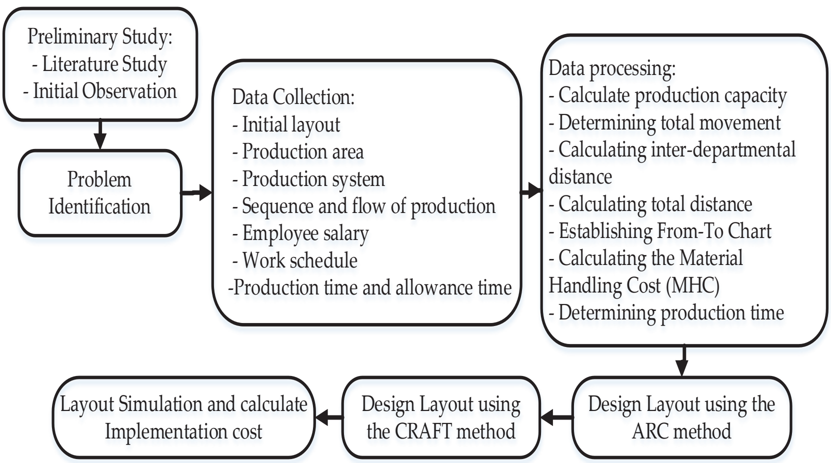


Figure 1. Research steps

3.0 RESULTS AND DISCUSSION

The present layout of the facility is the initial input required for the ARC and CRAFT techniques. The present layout is depicted in Figure 2.

In the slipper production process consists of 2 materials, material 1 starts from A to B. The second material starts from H to B, then the two materials are put together, then goes to C. from station C to D, then returns to C and goes to F then returns to C then to G. from G to E. back to F and to G, then from F to J and from G to J.

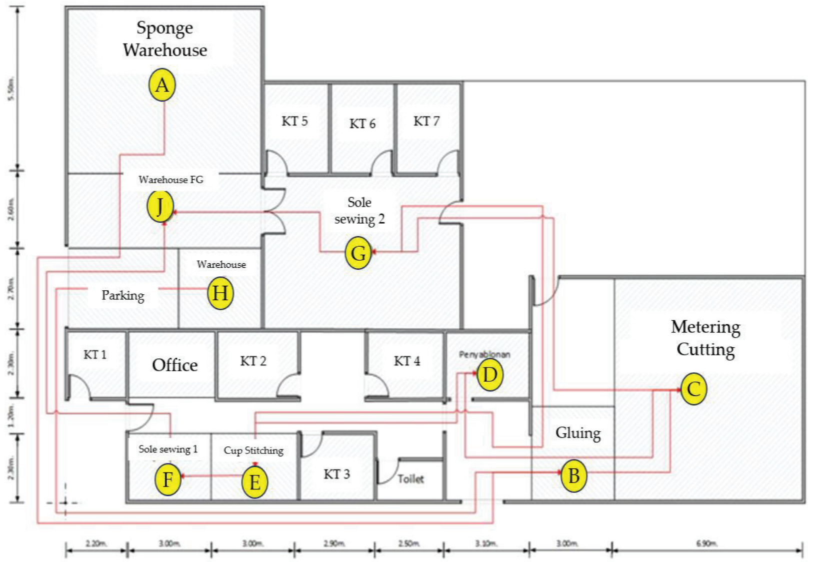


Figure 2. Existing Layout

3.1 Production Capacity

The production capacity for an employee is determined using the productive hours (total hours' minus employee allowance) for each department and then multiplying by the total number of working days as show in Equation 1, the result of the calculation as show in Table 1.

$$\frac{working\ hours - allowance\ time}{process\ time} \times working\ days \tag{1}$$

Table 1. Production Capacity

Dept. Code	Operator Code	Capacity (unit product)
B	Opt. 10	213
	Opt. 11	230
	Opt. 12	230
C	Opt. 10	743
	Opt. 11	795
	Opt. 12	809
D	Opt. 4	6.989
	Opt. 5	6.809
E	Opt. 9	11.276
F	Opt. 8	990
G	Opt. 13	1.027
	Opt. 14	984
	Opt. 15	1.047
	Opt. 16	1.213
	Opt. 17	1.264
	Opt. 18	1.133

3.2 Frequency of displacement

The frequency of displacement is computed using the number of units and dividing it by conveyance capacity as show in Table 2. Unit movement is determined by observation. Transport capacity is determined using the number of units moved and the transport equipment required to move those units [11].

3.3 Inter-departmental distance of the center every department

The center for every department is used as a reference to determine the distance between the departments using the x- and y-axis [1]. Once the center point is determined, the distance between adjacent workstations can be determined. The rectilinear distance formula is used to calculate distance as show in Equation 2:

$$d_{ij} = \left|x_i - x_j\right| + \left|y_i - y_j\right| \quad (2)$$

d_{ij}: the distance between i to j
x_i : position i on the x axis
x_j : position j on the x axis
y_i : position i on the y axis
y_j: position j on the y axis

Considering the current layout, the inter-departmental distance is computed using center coordinates. Using the material displacement and frequency calculations in Table 2, the total distance moved during production can be calculated, in this case 1,437.90 m.m.

Table 2. Frequency

From	To	Production Capacity (unit product)	Transport Capacity	Frequency (real)
A	B	673	30	23
H	B	673	100	7
B	C	5.869	900	7
C	D	6.900	600	12
C	F	990	320	4
C	G	6.668	960	7
D	E	5.638	520	11
E	F	990	320	4
E	G	6.668	960	7
F	J	990	320	4
G	J	6.668	900	8

3.4 Material Handling Cost (MHC)

Material Handling Cost (MHC) is based on a per-unit-time basis (month) because the company does not provide payments for material activities. Considering the current layout, the monthly MHC value is determined based on all handling activities carried out by all operators, which is IDR 522,268. -/ month.

3.5 Design Layout using ARC Method

In the case of UKM Azka Pratama, the ARC method-based design requires determining the relationship between activities, which is based on interviews and observations specific to the present layout. The activity relationship chart is depicted in Figure 3.

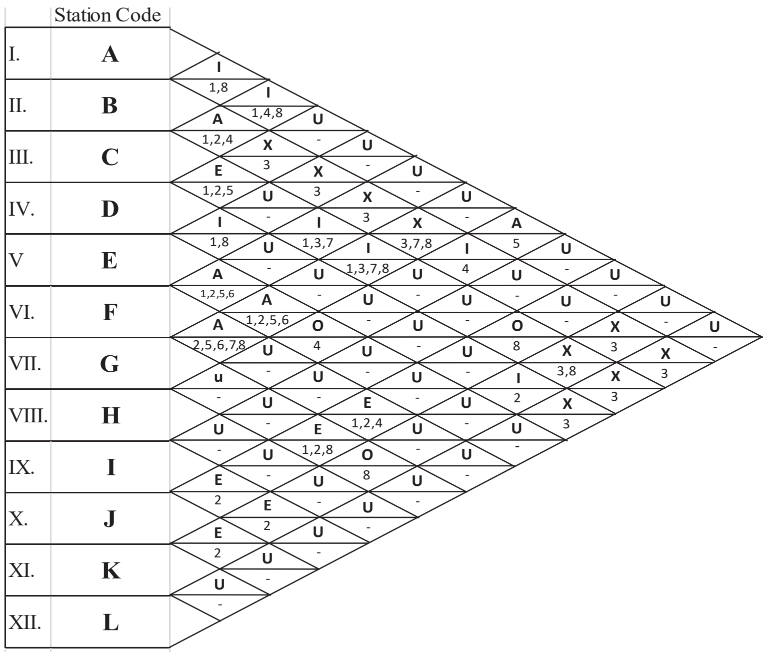


Figure 3. Activity relationship chart (ARC)

The ARC technique needs 13 changes to eliminate waste. The changes were made to the sponge and fabric warehouses, which were moved to near to the material collection and measurement departments. Measurement and cutting should be near to the gluing stations to decrease disruptions because of latex glue spraying. The printing department was moved to be proximal to the roads. At the same time, cup and sole sewing must be proximal to sole sewing stations, thereby leading to an integrated area having a parking lot to facilitate transport. Figure 4 depicts the layout proposed using the ARC method.

3.5.1 Total distance using the ARC-proposed layout

The material transfer frequency and new material transfer distance calculations from Table 2 facilitate the calculation of the total distance required for production. The ARC-proposed layout requires a total movement of 943.45 m, which corresponds to a reduction of 34.39%.

3.5.2 MHC considering the ARC-proposed layout

Determination of MHC using the ARC method-based design requires the operator's knowledge of the speed of material movement in the current layout so that it can be compared with the time required in the proposed layout. The material transfer rate of all operators for the current layout is 1m / s, so it can be determined that the new layout makes for faster movement and less moving time. Considering the operator's speed in calculating the transfer time, the proposed layout using the ARC technique provides a savings of 26.52%, which means MHC (per month) of IDR 301,576.53, representing a savings of 42.26%.

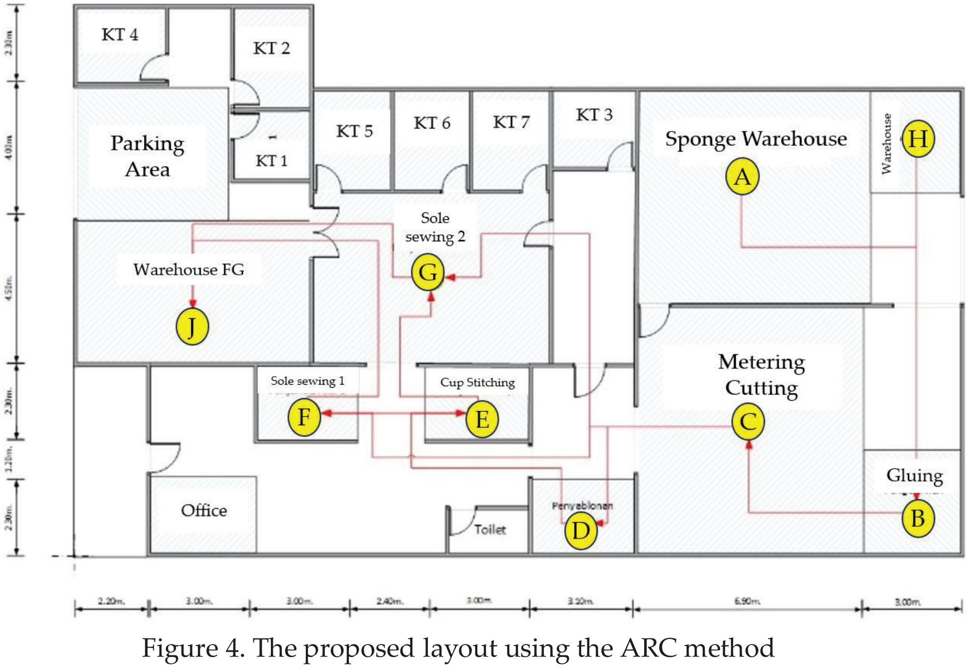


Figure 4. The proposed layout using the ARC method

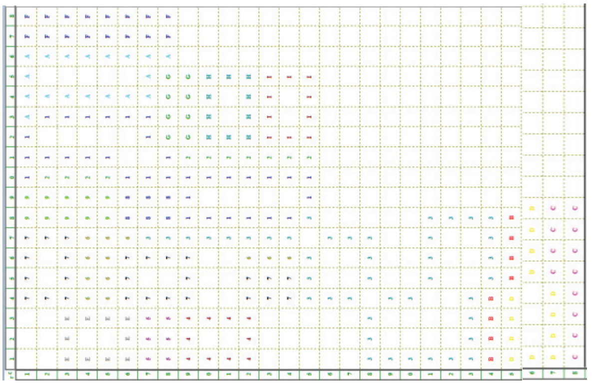
3.6 Design Layout using CRAFT method

The CRAFT method calculations were conducted using the WinSQB software, and four other layout recommendations were provided. These solutions and the processing results using the software are specified in Table 3.

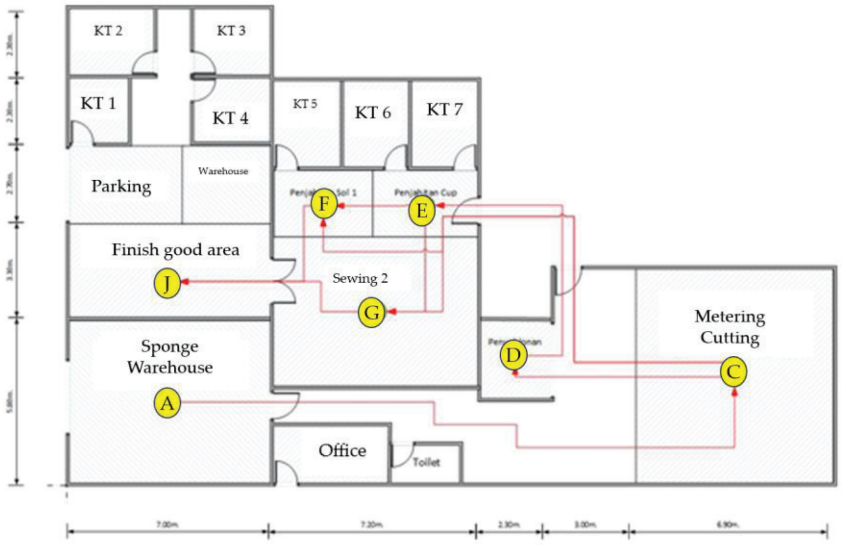
Table 3. The WinQSB Result

WinQSB Solutions	Iteration	Total Cost
Evaluate the initial layout only	0	1.486,81
Improve by Exchanging 2 departments	9	817,40
Improve by Exchanging 3 departments	7	1.006,51
Improve by Exchanging 2 then 3 departments	9	817,40
Improve by Exchanging 3 then 2 departments	14	664,83

Based on Table 3, it can be observed that the CRAFT-based solution reduces waste in terms of material movement time. The smallest optimization can be achieved by exchanging three departments followed by two, where 14 iterations are required to achieve the optimal conditions for 664.83. There is a total of 9 department changes associated with this layout change, where the sponge warehouse should be moved to the second sole sewing station since it has a similar size. The second sole sewing station should relate to first suturing sol. The bedroom, silk-screening, and sewing cup positions are switched to create a smoother flow. The office and bedroom move to the back where they are in proximity to the measurement and cutting area. The gluing station moves next to the screening station so that there is no material flow during displacement. Figure 5 (a) show results generating new layout form base on optimization of coordinate and distance and Figure 5 (b) show the proposed layout after running CRAFT approach by *WinQSB* software.



(a)



(b)

Figure 5(a) Final layout generated by software WinQSB V3.0 and (b) The proposed layout by the CRAFT method

3.6.1 Total Distance for Alternative CRAFT Layouts

The calculations from Table 2 may be employed to determine material transfer frequency and distance, which may be used to calculate the total distance traversed during production. The proposed CRAFT-based layout has a total distance of 664.82 m, which translates to savings of about 63.76%.

3.6.2 MHC for Alternative Layout using CRAFT

The CRAFT technique also requires operator speed concerning material transfer in the present layout, thereby affecting material handling cost (MGC). Table 5 provides information specific to interdepartmental material movement speed and changes in time required. Considering operator-specific aspects, material movement time for the CRAFT-proposed layout provides time savings of 37.13%, leading to a monthly MHC of IDR. 144,113.81, indicating savings of 72.41%. Reducing material movement time with the CRAFT method can be successful and effective, this is similar to what was done by Wahyuni and Safitri [9], Yuliana et al [12].

3.7 Layout Simulation

The ARC- and CRAFT-proposed layouts shall be simulated using ARENA software to observe the improvement in production visually.

Both techniques lead to enhanced production. The production increase for the ARC-based and the CRAFT-based methods was 4.19% and 2.39%, respectively. This is in line with the study conducted by Faishal et al in order to reduce waste of transportation [13]

3.8 Implementation Cost

The renovation cost is computed using 2018 prices and assumptions applicable for that time. The wall construction cost is IDR. 279,000 per meter, while wall disassembly costs IDR. 100,000 per day. Considering roof creation, the cost is IDR. 250,000 per square meter, while the cost for two individuals providing the workforce is IDR. 180,000 per day. Every layout proposal is expected to take two weeks; hence the cost for renovating the premises as per the proposed ARC-based layout is IDR. 31,428,900. In comparison, the total renovation cost using the CRAFT-based layout is IDR. 9,437,000.

4.0 CONCLUSION

SME Azka Pratama specializes in producing high-quality sponge slippers well-known for their comfort. Presently, the company has design-layout challenges since there are several wastages during material transport. This wastes causes an extended production time and reduces throughput. Hence, the study aims to produce an optimized facility design to minimize wastes in material handling time. The CRAFT technique was used, and the layout of the office area, gluing and screening stations, sewing sols 1 and 2, and rooms 1-4 were relocated. The redesign led to a 53.76% reduction in distance, while the MHC was reduced by about 37.13%. These optimizations facilitated a throughput increase of 2.39%. In contrast, the sponge and fabric warehouse optimizations were performed using the layouts obtained from the ARC method. These were moved closer to the material cutting and measurement stations. Subsequently, the measurement and cutting stations were switched with the gluing department to lessen the disruption caused by the latex glue spraying process. Additionally, the screen-printing station was also moved to facilitate better access to the road. The cup and sol 1 sewing stations were moved closer to the sol 2 sewing station, which causes the room to be in proximity to the parking area for optimized activity. The ARC method facilitated distance and time optimization by 34.29% and 26.52%, respectively, thereby leading to the throughput increasing by 3.75%. The ARC-based layout was proposed after obtaining data from the employees. Questionnaires were employed to assess how the employees understand the optimal and friendly layout. However, the cost of implementation is high. In comparison, the layout proposed using the CRAFT technique provided the least total distance and optimal the material handling time with the low cost implementation; hence, the layout proposed using the CRAFT technique is more apt than others.

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AUTHOR CONTRIBUTIONS

Conceptualization, M. Faishal.; methodology, M. Faishal.; software, M.A. Pratama, and O. Adiyanto.; re-sources, M.A. Pratama ; writing—original draft preparation, M. Faishal.; writing—review and editing, E. Mohamad and A.A. Abdul Rahman.; supervision, E. Mohamad., and A.A. Abdul Rahman. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest on the manuscript.

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