MINIMIZATION OF MATERIAL HANDLING COST IN FUZZY ENVIRONMENT

THESIS

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This report dedicated to my beloved parents and sister,

for the support and love

also to all my friends,

for the spirit that all of you gave to me.

MOTTO

"Allah (Alone) is Sufficient for us, and He is the Best Disposer of Affairs (for us)."
-Quran Al 'Imraan 3:171

"And be moderate (or show no arrogance) in your walking, and lower your voice."
-The Quran Luqman 31:19″

"A bad attitude spoils a good deed just as vinegar spoils honey"

-Muhammad SAW

"At the end of the storm, there's a golden sky"

-Bill Shankly

"Live the life you love, love the life you live"

-Bob Marley

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Minimization of Material Handling Cost in Fuzzy Environment

By

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Submitted to Industrial Program, Department of Industrial Engineering, Faculty of Industrial Technology, on September in partial fulfillment of the requirement for the Degree of Sarjana Teknik Industri Universitas Islam Indonesia.

ABSTRACT

Material Handling Cost is one of most important thing to be considered in designing the facility layout. The challenge is to create optimal layout or improve the initial layout. This study will proposed a fuzzy mamdani model approach to obtain the Crisp Activity Relationship Chart (CARC) that will be used to develop layout using CORELAP, one of algorithm technique in designing the facility layout. Then the final CORELAP layout will be maximized using Computerized Relative Allocation for Facilities Technique (CRAFT). The result of this study showed that the fuzzy approach could be an alternative in more precise quantitative analysis. Hence, resulted more minimum material handling cost.

Keywords: Facility Layout, Fuzzy Logic, Mamdani Model, CARC, CORELAP, CRAFT, Material Handling Cost

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INTRODUCTION

1.1 Background

Facility layout planning is very important in determine the location and layout. The application of facility layout planning can be found in many places, from offices to manufacturing. Especially for manufacturing, facility layout planning will be an important issue because if the layout placed correctly, so the manufacturing system will be optimal. Moreover, layout has important role in material handling. Sule (1994) mentioned that material handling itself can account for 30-75% of the total cost. No other things that give more effect for the operational cost but the material handling. The further impact, the manufacturer can reduce the cost, gain the optimal production, reduce the selling price and survive in competitive market.

Many researches about facility layout design have been done. One of them proposed by Raoot and Rakshit (1993), using linguistic pattern for multiple criteria facility layout. The problem-solving methodology illustrated with numerical example and directions to select facility layout from the set of alternatives. Activity relationship chart (ARC) is the main considering factor to determine the location and design, beside the space requirements of each location. Further, fuzzy decision-making system was proposed by Dweiri (1999) to determine the ARC. The object of the research is to change the traditional ARC into crisp activity relationship chart (CARC). CARC is obtained from fuzzy set approach and it is resulting more precise closeness rating rather than traditional ARC. The CARC further can be used to develop the layout using some technique such as CORELAP, ALDEP, etc. Deb and Bhattacharyya (2005) develop facility layout that minimize flow cost, dead space and area required for the development of layout, using fuzzy decision support system. The layout developed using multifactor-normalized selection routine.

Problem that usually found in determining the facility and location is the closeness rating in ARC. Where it is determined by subjective qualitative analysis of the designer based on designer’s knowledge which is A, E, I, O, U, X as the output. If the design was considered by subjective, the final layout will not optimal yet, and the cost of the material handling will be also high.

Hence, in order to minimize the material handling cost, a new method is needed to change the closeness rating in ARC that subjective into more objective value. The objective value can be derived by calculating a crisp number. One of the method that can be used to obtained crisp number is fuzzy approach and resulted CARC. Then, the CARC can be used as considering factor in developing a new layout using CORELAP, ALDEP, etc.

1.2 Problem Formulation

Based on the background above, the main problem of this research can be formulated as follows:

a. How to change ARC into more objective CARC based on fuzzy approaches?

b. What is the optimal layout based on the most minimum material handling cost?

1.3 Problem Limitation

The limitations in this research are:

a. The research object is focused on PT Fumira, in the production department.

b. The layouts that will change are the areas in finishing line department that possible to be moved and some areas have fixed position.

c. The factors that will affect the layout are predetermined.

d. The cost of material handling is predetermined and will not change along examined period.

1.4 Research Objective

The purposes of this research are:

a. To develop the optimal layout based on CARC.

b. To create optimal layout based on most minimum material handling cost.

1.5 Research Benefits

The benefits of this research can be described as follows:

a. Provide alternatives approach for designer to determine the ARC, not just from qualitative but also quantitative.

b. The fuzzy model can also used in wider area, for example in determining the CARC for machines, building, offices layout, determining material handling equipment selection, etc.

c. The fuzzy decision-making system can be adapted to many applications other than in facility layout problem.

d. Able to combine the science knowledge with sense of the art.

1.6 Thesis Structure

The thesis structures are:

CHAPTER II LITERATURE REVIEW

This chapter includes the explanation of the previous researches that have been conducted at an earlier time about the thesis that is composed by the writer and also it provides the literature study that the writer is using in the process of composing the thesis.

CHAPTER III RESEARH METHODOLOGY

This chapter provides explanations that consist of the object of the research, building a model requirement of the data, which is required in completing the research which is divided into primary data and secondary data. The method of data collecting that involves field research, both direct observation and interview, tool of analysis data, framework of research methodology.

CHAPTER IV DATA COLLECTION AND PROCESSING

This chapter presents information of data that have been collected during the research. It also contains the problem solving using the proposed model or tools that are implemented in processing the data, as well the analysis of the processed data using the proposed model or tools.

CHAPTER V DISCUSSION

This chapter provides a discussion about the data that has been collected during the research and also the result of processed data. Furthermore, it also discuss about the result in order to see whether the proposed model or tools are able to solve the problems that are formulated at an earlier time of the research.

CHAPTER VI CONCLUSION AND RECOMMENDATIONS

This chapter presents about the conclusions of the research that conducted and recomendation of the further research.

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CHAPTER II

LITERATURE REVIEW

2.1 Previous Research

Many researchers have concerning to the facilities layout issues. Due to the complex and unstructured nature of facility layout, Deb and Bhattacharyya (2004) mentioned that many researchers have proposed various approaches, which had varying degrees of success in dealing with the complexities associated with the problem.

Karwowskij and Evans (1987) illustrated the potential application of fuzzy set theory to various areas of production management. The heuristic utilizes two distinct design categories which are closeness and importance and expressed using fuzzy relations. One of the well-known areas identified by the authors was facility planning which includes such problem as facilities layout design. Raoot and Rakshit (1993) have also presented a framework of an algorithm for the development and evaluation of a layout based on fuzzy linguistic variables and their fuzzy relation.

Further, a fuzzy decision-making application for developing relationship charts and comparing the layouts generated with them were proposed by Dweiri (1999), which suggested further research work to improve the procedure or developing a new algorithm for the facility layout design. The facility layout problems fall in to the class of NP-complete solutions, and heuristic approaches are usually adopted to develop the layout

(Heragu and Kusiak, 1990). Most of the models and algorithms available in the literature are based on the quadratic assignment problem with an objective to minimize transportation costs or maximize total closeness rating. The facility selection routine required for the development of layout was solved by considering a single quantitative factor as flow chart. Moreover, the move (distance) traversed is considered from center to center of the departments without considering the practical issue of entry and exit of the departments (Deb and Bhattacharyya, 2005).

In their proposed research, Deb and Bhattacharrya (2005) continued the previous research using the same direction that proposed by Dweiri (1999). With the objective to minimize the area of layout and dead space, the result was that the required area of the layout and dead space of the layout are lower by using multifactor fuzzy method, but the flow cost was slightly higher.

Since the previous research not concern about the minimization of the flow cost yet, this paper will develop the research that could minimize the flow cost of the facilities that developed by fuzzy method. The minimal flow cost will be obtained from optimal layout that developed from the initial layout.

2.2 Basic Theory

2.2.1 Facility Design

Facilities can be broadly defines as buildings where people, material, and machines come together for a stated purpose—typically to make a tangible product or provide a service. Due to various internal and external forces, the facility must be properly managed to achieve its stated purpose while satisfying several objectives. Such objectives include producing a product or providing a service at lower cost, at higher quality, or using the least amount of natural resources. To manage facilities so that the objectives (which often conflict with one another) are attained, one must understand the underlying decision problems faced in such systems.

In recent years manufacturing and service industries have witnessed several developments, as shown by the increase in the number and types of automated systems. However, these developments have brought along attendant system design problems. As the design problems have grown even more complex, designers and users of automated system have had develop new tools to cope with these problems. Manufacturing or service system design encompasses several problems. This complex activity involves solving a number of designs and planning problems arranged in a hierarchy.

Additionally, some of the more important design questions that need to be addressed are pre elimination process plan development, determination of tooling and fixture requirements, layout of manufacturing cells and machines, material-handling devices capable of performing the required material-handling moves. Solving manufacturing cell determination and cell layout problems is generally required for only manufacturing systems that produce a large number of components and for which manufacturing activities can be divided into almost mutually independent cells (Heragu, 1997).

Heragu (1997) mentioned that the location scoring method using subjective decision-making tool that is relatively easy to use. It consissts of five steps:

1. List all the factor that are important that have an impact on the location decision.
2. Assign an appropriate weight (typically between 0 and 1) to each factor based on the relative importance of each.
3. Assign a score (typically between 0 and 100) to each location with spect to each factor identified in step 1.
4. Compute the weighted score for each factor for each location by multiplying its weight by the corresponding score.
5. Compute the sum of the weighted scores for each location and choose a location based on these scores.

Several quantitative techniques are available to solve the discrete space, single-facility location problem. Each is appropriate for a specific set of objectives and constraints. For example, the so-called minimax model is appropriate for determining the location of an emergency service facility, where the objective is to minimize the maximum distance traveled between the facility and any customer. Similiarly, if the objective is to minimize the total distance traveled, the transportation model is appropriate (Heragu, 1997).

2.2.2 Facilities Planning

Facility layout deals with the selection of the most efficient layout of physical departments in a production plant or a service facility in order to operate cost effectively. The block layout design seeks the best arrangement of departments based on their interrelationships and involves the location of departments within the available area. In the design process of the layout many objectives must be considered. Tompkins and White (1984) listed the following as typical facilities design objectives:

1. Support the organization's mission through improved handling and control of materials.
2. Effectively utilize people, equipment, space and energy.
3. Minimize capital investment.
4. Be flexible and promote ease of maintenance.
5. Provide for employee safety and job satisfaction

Space requirements of the departments and the activity relationships among these departments are important factors in determining the design of a facility layout. Activity relationships influence the location and design of a department. Space requirements determine the size of a department and influence the overall design of the layout. The facility design process is an iterative process, especially as it relates to determining interrelationships among all departments (activities) and space requirements for all activities. Facilities design objectives and activity relationships provide the basis for many decisions in the facilities planning process (Dweiri, 1999).

2.2.3 Activity Relationship Chart

ARC is based on judgment of experts who decide the relationship between each pair of departments in the plant. This decision is vague and usually based on many quantitative or qualitative considerations. The flow of materials between departments and the ease of supervision of employees in the departments are examples of such vague issues. The ratings of these relationships are described in the table below:

Table 2.1 Closeness Rating table

Closeness Rating	Description
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary
U	Unimportant
X	Undesirable

Then the closeness ratings are considered analytically in each departments and the reason for the assigned rating is indicated using a numeric code. The reasons are determined by the designer regardless of their quantitative or qualitative nature (Heragu, 1997).

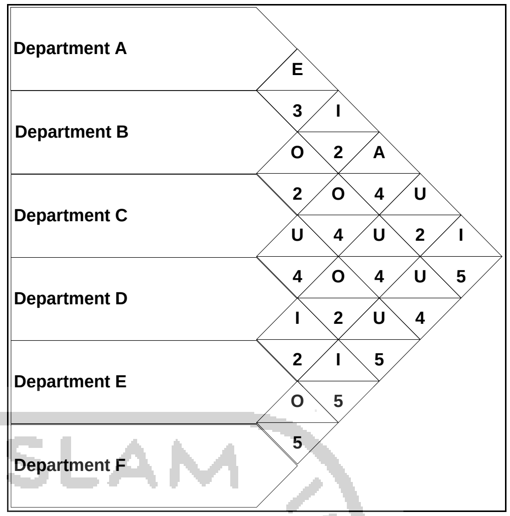


Figure 2.1 Example of ARC

2.2.4 Material Handling

Several definitions are available for material handling. The most comprehensive is the one provided by the Material Handling Institute (MHI), which states: "Material handling embraces all of the basic operations involved in the movement of bulk, packaged, and individual products in a semisolid or a solid state by means of machinery, and within the limits of a place of business."

Even a cursory examination of the statement reveals that material handling involves much more than just moving the material by using machinery; several additional functions are implied in the system.

First, material handling involves the movement of material in a horizontal (transfer) and a vertical (lifting) direction, as well as the loading and unloading of items. Second, specifying that the movement of materials is "within a place of business" implies that the movement includes raw materials to work stations, semifinished products between work stations, and removal of the finished products to their storage locations. It also distinguishes material handling from transportation; the latter involves moving materials from suppliers to places of business or from places of business to customers.

Third, the selection of handling equipment is another activity in designed material-handling systems. Fourth, the term *bulk* indicates that the materials are to be moved in large, unpackaged volumes such as sand, sawdust, or coal. And fifth, using machinery for handling material is the preferred method even though the initial cost might be high. The use of human beings on a continuous basis is inefficient and can be costly; material-handling equipment soon pays for itself, especially in societies in which the cost of labor is high (Sule, 1994). The objectives of material handling can be described as follow:

a. To increase the efficiency of material flow by ensuring the availability of materials when and where they are needed.
b. To reduce material-handling cost.
c. To improve facilities utilization.
d. To improve safety and working conditions.
e. To facilitate the manufacturing process.
f. To increase productivity.

2.2.5 Material Handling Cost

The main costs involved in designing and operating a material-handling system are:

a. Equipment cost, which comprises the purchasing of the equipment and auxiliary components, and installation.
b. Operating cost, which iincludes maintenance, fuel, and labor cost, consisting of both wages and injury compensation.
c. Unit purchase cost, which is associated with purchasing the pallets and containers.
d. Cost due to packaging and damaged material.

Reducing such cost is one of the primary objectives of a handling systems. There are several ways of achieving this goal. For examples, one can minimize the idle time of the equipment. High utilization of equipment will eliminate the need to acquire extra units. One can be minimize rehandling of material and backtracking, thus reducing operating cost. One can arrange closely related departments near each other to result in material being moved only short distance. One can precent excessive repairs by planning maintenance activities in advance. One should use proper equipment to reduce material damage and use unit loads whenever possible. The gravity principle should be used whenever possible, since it can reduce operating cost. One should eliminate unsafe practices by employees such as lifting heavy items; this will reduce injuries and consequent worker compensation. One can minimize the variations in equipment types, thus eliminating the need for an inventory of a variety of spare parts and their associated costs. One can replace obsolete equipment with new and more efficient ones when the savings justify it. As the reader probably realized by now, we are again applying the twenty principles of material handling.

2.2.6 Fuzzy Logic

Most of traditional tools for formal modeling, reasoning, and computing are crisp, deterministic, and precise in character. By crisp mean dichotomous, that is, yes-or-no-type rather than more-or-less-type. In conventional dual logic, for instance, a statement can be true or false □ and nothing in between. In set theory, an element can either belong to set or not; and in optimization, a solution is either feasible or not. Precision assumes that the parameters of a model represent exactly either our preception of the phenomenom modeled or the features of the real system that has been modeled. Generally precision also implies that the model is unequivocal, that is, that it contains no ambiguities.

Certainly eventually indicates that we assume the structures and parameters of the model to be definitely known, and that there are no doubts about their values or their occurence. If the model under consideration is a formal model, that is, if it does not pretend to model reality adequately, then the model assumptions are in a sense arbitrary, that is, the model builder can freely decide which model characteristics choosen (Zimmermann, 1991).

1. Fuzzy Set Theory

Dweiri (1999) mentioned that fuzzy set theory was introduced to deal with vague, imprecise and uncertain problems. The lack of data is the reason for uncertainty in many daily problems. Fuzzy set theory has been used as a modeling tool for complex systems that are hard to define precisely, but can be controlled and operated by humans.

Saying that some concept is imprecise and using that imprecision in a model are two different things. The bridge between them is the concept of a fuzzy set. To see how these properties are used in constructing an actual fuzzy set, consider the concept of TALL applied to American males. Given a particular value for an individual's height, what values are considered tall? In classical set theory, forced to choose an arbitrary cutoff point, say, six feet. Since the boundaries between what is in a set and what is outside a set are very sharp, these types of constructs are called crisp sets. A characteristic function for such a set appears as,

$$\mu_{TALL} = \{\text{height} \geq 6\} \quad (2.1)$$

Thus anyone over six feet is tall. The membership graph for this set appears in figure 2.2

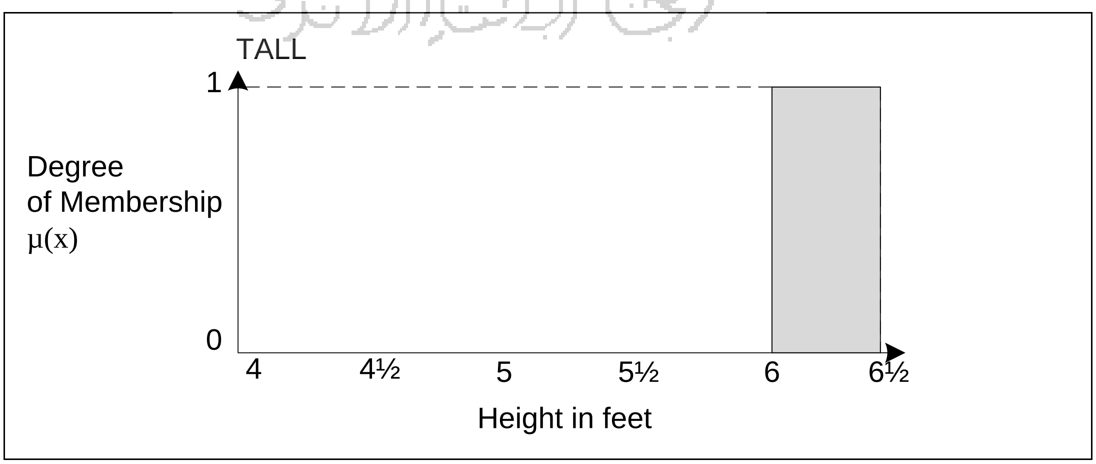


Figure 2.2 The Crisp Set for the Concept TALL

The discriminant or characteristic function for this set reflects its Boolean nature. As we move along the domain, the membership of heights in the set tall remains false (zero) until reach exactly six feet when it jumps immediately to true (one). Note that in the membership transition graph for crisp sets the line connecting nonmembership and membership is dimensionless. All classical or crisp sets have this kind of membership function. Although this dischotomization of the sample space may work well for grainy, lumpy, and other noncontinuous collections, it generally fails when applied to phenomena that have a continuously (and monotonically) changing set of values.

The ideal of TALL, illustrated in Figure 2.2, is the classical example of a fuzzy set and illustrates the intrinsic properties of fuzzy spaces. The domain of this set, indicated along the horizontal axis, is the range of heights between four feet and six and a half feet. The degree of membership or truth function is indicated on the vertical axis to the far left. In general, the membership goes from zero (non membership) to one (complete membership). The membership function and the domain are connected, in this casem by a simple linear curve (tallness is directly proportional to height). Now, given a value for height, we can determine its degree of membership in the fuzzy set.

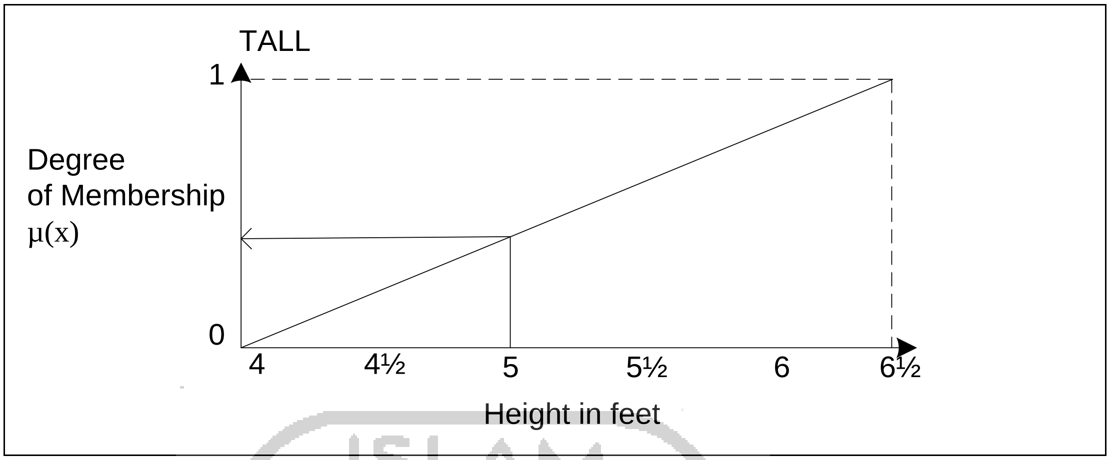


Figure 3.2 Determining the Degree of Membership in TALL

Thus a height of five feet has a [.46] degree of membership. The interpretation of this value corresponds to the truth of the proposition.

Five feet is TALL

If the value for height is less than four, it membership is zero. If the height is greater than or equal to 6.5 feet, then its membership value is one. This membership function is interpreted as a measure of the compatibility between a value from the domain and the idea underlying the fuzzy set. In the case of 5 feet, the membership of [.46] means that it is moderately but not strongly compatible with the notion of TALL. As the membership value moves toward zero the sample becomes less and less compatible with the semantics of the fuzzy set and, as the membership value moves toward one, the samples becomes more and more compatible with the fuzzy set's semantic property.

A collection of objects (universe of discourse) *U* has a fuzzy set A described by a membership function μ_A that takes values in the interval [0, 1], $\mu_{A:}\ \mu_{A:}\ U \rightarrow [0, 1]$. Thus A can be represented as:

$$A = \{(\mu_A(u)/u) \mid u \in U\} \quad (2.2)$$

The probability that u belongs to A is the membership function $\mu_A(u)$

2. Fuzzy Linguistic Variables

Linguistic variables take on values that are words in natural language, while numerical variables use numbers as values. Since words are usually less precise than numbers, linguistic variables provide a method to describe complex systems that are ill-defined in traditional quantitative terms.

A linguistic variable is defined by the name of the variable *x* and the set term *T(x)* of the linguistic values of *x*, with each value being a fuzzy number defined on *U*. For example, if temperature is a linguistic variable, then its term set *T* (temperature) = {high, medium, low, . . .}, where each term is characterized by a fuzzy set in a universe of discourse *U* = [0, 100], as shown in Fig. 2.2. The figure show that 70^0F belongs to the linguistic variables {high, medium and low} with membership values of {0.33, 0.67, 0} respectively. Using the maximum value to find the fuzzy set that this temperature value belongs to, 70^0F belongs to the fuzzy set *medium* with a membership value of 0.67 (Dweiri,1999).

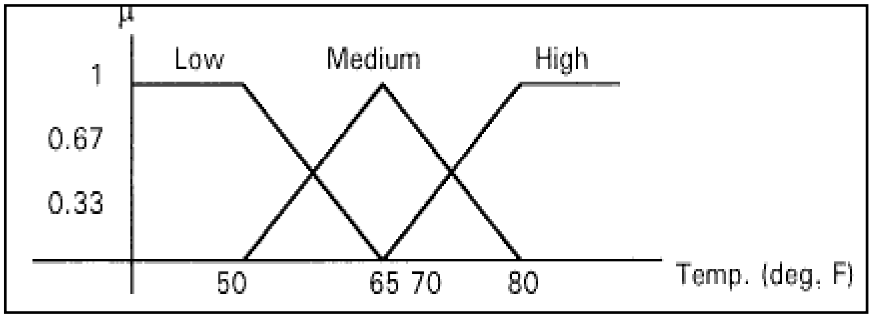


Figure 2.4 Membership functions for temperature.

3. Fuzzy decision-making system

A fuzzy decision-making system (FDMS) consists of four main components as shown in figure below.

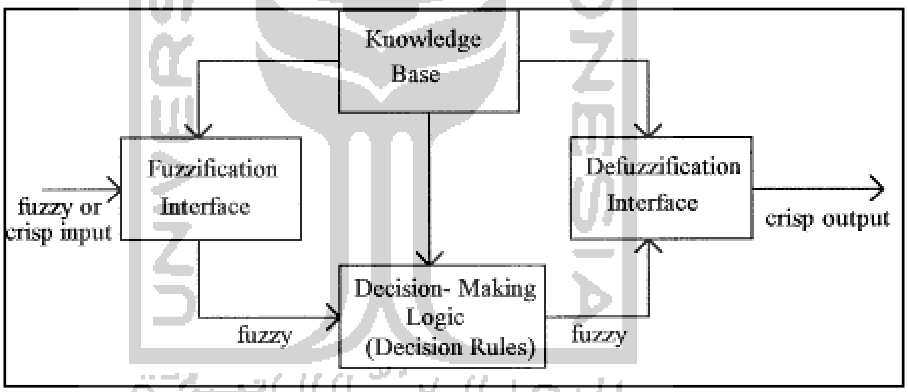


Figure 2.5 Basic configuration of fuzzy decision making system (FMDS)

The four principal components of the fuzzy decision-making system are:

a. The fuzzification interface

Measures the values of the input and output variables, transfers the range of these values into a corresponding universe of discourse, and converts them into natural language (high, low, very low, etc.).

b. The knowledge base

A database that contains the experts' knowledge of the application and the control rules of the process. The membership functions are decided by the experts based on their knowledge of the system. The fuzzification process is defined at this point.

c. The decision rules

Simulates the experts' decision-making ability based on a fuzzy concept. The connective 'and' is implemented as a fuzzy conjunction in a Cartesian product space in which the input variables take in their respective universe of discourses. The number of rules used in controlling the system using fuzzy control is represented by

$$K = \sum_{j=1}^{m} \left(\prod_{i=1}^{n} Li \right) \tag{2.3}$$

Where:

K=total number of rules

m=the number of the sets of rules using one set of variables

n=the number of input variables used in a set of rules

L=the number of fuzzy sets in an input variable

Example of common rules:

Rule 1: If temperature is high AND lighting is low THEN productivity is low

Rule 2: If temperature is medium AND lighting is high THEN productivity is high

d. Defuzzyfication

To combine all the related rules for any activity in the layout, we need to use a defuzzyfication method. One of the most common methods is the center of gravity (COG) method. This method is shown below.

$$R_o \frac{\sum_i (\mu g_R \times R)}{\sum_i \mu g_R}, \tag{2.4}$$

Where:

*R*o=final crisp rating of the activity

g=the fuzzy rating of the activity for the rule in consideration

i=the rules that are used in the activity

R=the numerical rating of the rule

m=the membership value of the activity for rule

2.2.7 CORELAP

CORELAP is one of the first construction algorithms that was developed and "computerized" (Lee and More, 1967). It converts qualitative input data into quantitative data and uses this information to determine the first facility to enter the layout.

Subsequent facilities then added to the layout, one at time, based on their level of interaction with facilities already in the layout. The qualitative flow data are based on the relationship chart that uses the codes A, E, I, O, U, and X to describe the adjacency requirements for facility pairs. The codes then assigns to numeric values i.e. 6, 5, 4, 3, 2, and 1 to the relationship indicators A, E, I, O, U, and X, respecctively.

Unlike most other algorithms, which use the distance between the centroids of facilities, CORELAP uses the "shortest path" distance measure. The distance between any two facilities is equal to the number of unit squares between them (Heragu, 1997).

Department selection steps in CORELAP:

a. The first department placed in the layout is the one with the greatest Total Closeness Rating (TRC) value. If there is a tie, then choose the one with more A's (E's, etc.)
b. If a department has an X relationship with the first one, it is placed last in the layout. If a tie exists, choose the one with the smallest TCR value
c. The second department is the one with an A relationship with the first one (or E, I, etc.). If a tie exists, choose the one with the greatest TCR value
d. If a department has an X relationship with the second one, it is placed next-to-the-last or last in the layout. If a tie exists, choose the one with the smallest TCR value
e. The third department is the one with most A (E, I, etc.) relationships with the already placed departments. If a tie exists, choose the one with the greatest TCR value
f. The procedure continues until all departments have been placed.

Table 2.2 Example of Relationship Chart

Dept	A	B	C	D	TCR	Order
A		A	I	U	6	4
B	A		I	A	10	1
C	I	I		E	7	2
D	U	A	E		7	3

A=4 E=3 I=2 O=1 U=0 X=-1

2.2.8 Computerized Relative Allocation of Facilities Technique (CRAFT)

CRAFT, which stands for Computerized Relative Allocation of Facilities Technique uses the 2-opt solution strategy to develop a layout but has some different implementiations. For example, CRAFT does not examine all possible pairwise exchanges before generating an improved layout. CRAFT requires the following input data:

a. Dimensions of the building in which the facilities are to be housed
b. Dimensions of the facilities
c. Flow ow material or frequency of trips between facility pairs, and cost per unit load per unit distance
d. An initial layout
e. Restrictions on the location of facilities, if applicable

Given the initial layout, CRAFT computes the distance between the centers of each facility pair and determines the cost of the initial layout. Note that the cost can be computed by determining these items for each pair of facilities:

a. Product of number of trips between facilities i and *j* and cost to make one trip between the two: and
b. Distance between facilities *i* and *j*.

CRAFT considers exchanging the locations of certain pairs of facilities. The facility pairs considered either have the same area or are adjacent. If all the facilities are of equal area or if every nonadjacent pair of facilities has the same area, then the algorithm can examine a maximum of possible exchanges in each iteration with expression:

$$n(n-1)/2 \tag{2.5}$$

Where:

n=number of facilities in the layout problem

In a general facility layout problem, the number of actual exchanges examined will be much less because not all facilities will have the same area. The location exchange that results in the greatest estimated cost reduction is made.

To calculate the estimated cost reduction, CRAFT interchanges the coordinates of facilities *i* and *j* whose exchange is being considered. If the exchange of facilities *i* and *j* is being considered, the cost reduction is estimated using this expression:

$$\sum_{k=1,k\neq i,k\neq j}^{n} f_{ik}\, d_{ik} + \sum_{k=1,k\neq i,k\neq j}^{n} f_{jk}\, d_{jk} - \sum_{k=1,k\neq i,k\neq j}^{n} f_{jk}\, d_{ik} - \sum_{k=1,k\neq i,k\neq j}^{n} f_{ik}\, d_{jk}$$

(2.10)

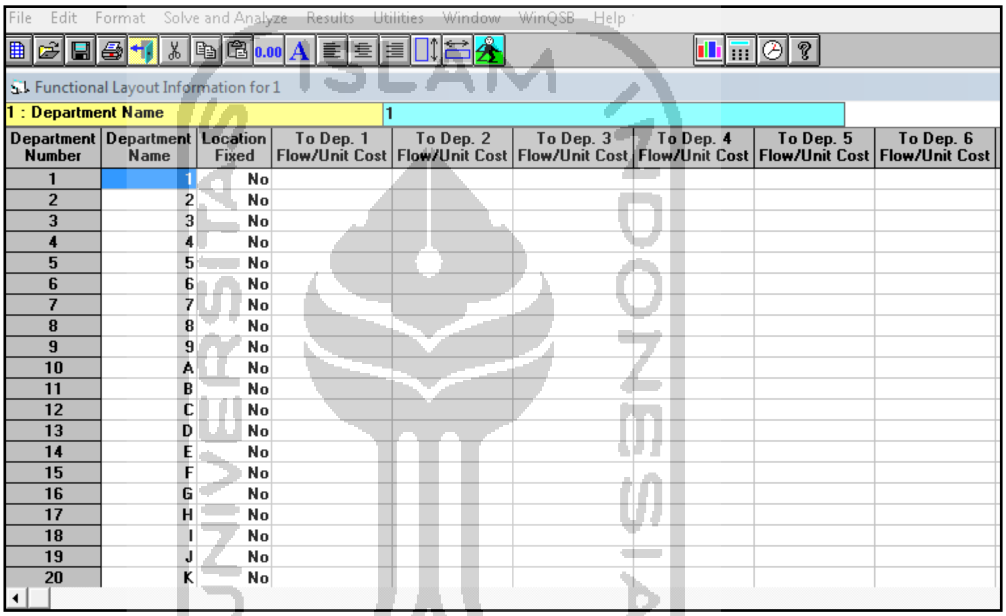
Where:

d_{ij}=distance between facilities i and j

f_{ij}=flow between facilities i and j

2.2.9 WinQSB

WinQSB is software that can solve several linear program problems, including Facility Location and Layout. The specific capabilities include solve single and multiple locations, allow three different distance measures, show location solution in graph, and for the line balancing problems. In this paper, WinQSB used to process CRAFT.



Department Number	Department Name	Location Fixed	To Dep. 1 Flow/Unit Cost	To Dep. 2 Flow/Unit Cost	To Dep. 3 Flow/Unit Cost	To Dep. 4 Flow/Unit Cost	To Dep. 5 Flow/Unit Cost	To Dep. 6 Flow/Unit Cost
1	1	No						
2	2	No						
3	3	No						
4	4	No						
5	5	No						
6	6	No						
7	7	No						
8	8	No						
9	9	No						
10	A	No						
11	B	No						
12	C	No						
13	D	No						
14	E	No						
15	F	No						
16	G	No						
17	H	No						
18	I	No						
19	J	No						
20	K	No						

Figure 2.6 Display of WinQSB

CHAPTER III

RESEARCH METHODOLOGY

This chapter will explain the object of the research, building a model requirement of the data, which is required in completing the research. The method of data collecting that involves field research, tool of analysis data, and framework of research methodology will be explained in sub-chapters as below:

3.1 Research Object

The study will be conducted at PT. Fumira. This research is focused on the machines layout in production department.

3.2 Mathematical Model

3.2.1 Mathematical Notation

1. Mathematical Fuzzy Logic

MF	: Number of material flow
EF	: Number of equipment flow
CR	: Closeness rating value
R	: Fuzzy rule
x	: Fuzzy universe of discourse of MF

y : Fuzzy universe of discourse of *EF*

k : constant value as consequences

R(r) : Fuzzy rule in number r

VL : linguistic variable for very low

L : linguistic variable for low

M : linguistic variable for medium

H : linguistic variable for high

VH : linguistic variable for very high

2. CRAFT

c_{ij} : Material-handling cost coefficient involved between location *i* and *j*

f_{ij} : Material flow volume between location *i* and *j*

d_{ij} : Distance between location *i* and *j*

n : Number of facilities

The assumptions made in this paper are:

a. Allowance include input area, output area, space for walk, and temporary storage.

b. In designing the new layout, there are some boundaries like rail road for transfer car.

c. Delivery area is area that inside the department, and it is not reduce the area of department itself.

d. Closeness Rating *(CR)* for departments that don't have relationship between them is 2.

e. Packaging must be located near the delivery area.

3.2.2 Fuzzy Logic Model

The Fuzzy logic model is described as follow:

1. Define Input and Output Variable

The input variables that related to the closeness rating in machines layout are number of material flow (*MF*) and equipment flow (*EF*). The output variable that will be resulted from considering the input variables is the closeness rating value (*CR*).

2. Fuzzy Set and Membership Function

Fuzzy set of (*MF*) and (*EF*) is shown in figure below.

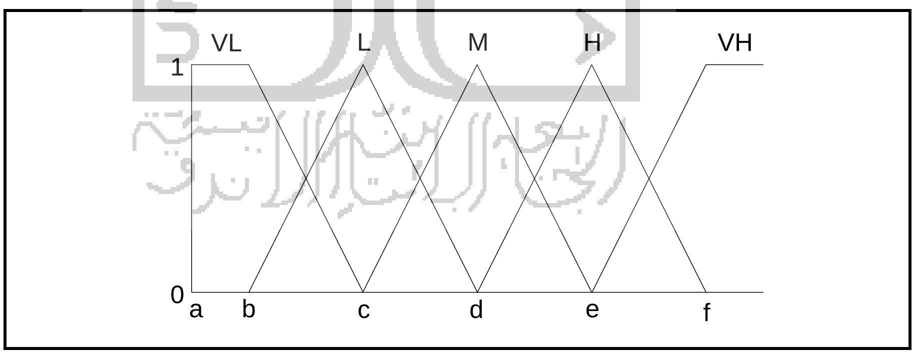


Figure 3.1 Representation of (*MF*)

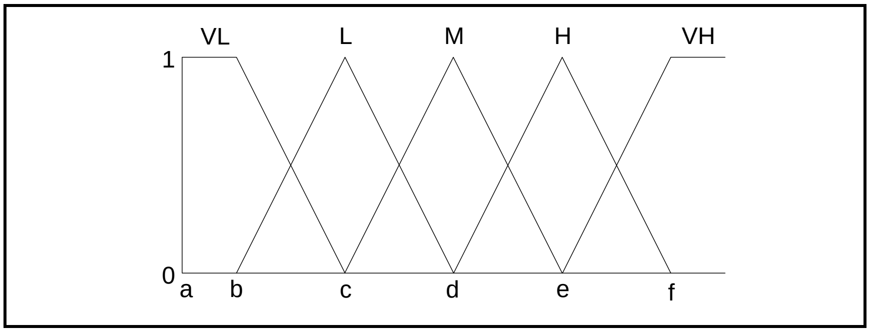


Figure 3.2 Representation of (*EF*)

Membership function:

$$\mu A\ VL\ (x) = \begin{cases} 0; & x \geq c \\ 1; & x \leq b \\ c - x/c - b\ ; & b \leq x \leq c \end{cases} \quad (3.1)$$

$$\mu A\ L\ (x) = \begin{cases} 0; & x \leq b \\ x - b/c - b\ ; & b \leq x \leq c \\ d - x/d - c\ ; & c \leq x \leq d \\ 0; & x \geq d \end{cases} \quad (3.2)$$

$$\mu A\ M\ (x) = \begin{cases} 0; & x \leq c \\ x - c/d - c\ ; & c \leq x \leq d \\ e - x/e - d\ ; & d \leq x \leq e \\ 0; & x \geq e \end{cases} \quad (3.3)$$

$$\mu A\ H\ (x) = \begin{cases} 0; & x \leq d \\ x - d/e - d\ ; & d \leq x \leq e \\ f - x/f - e\ ; & e \leq x \leq f \\ 0; & x \geq f \end{cases} \quad (3.4)$$

$$\mu A\ VH\ (x) = \begin{cases} 0; & x \leq e \\ x - e/f - e\ ; & e \leq x \leq f \\ 1; & x \geq f \end{cases} \quad (3.5)$$

3. Fuzzy Rule

The numbers of rules for fuzzy inference system from combination of 2 variables are 25. The equation is shown below:

$R_{(r)}$ = IF *MF* is *x* AND *EF* is *y* THEN *CR* = *k* (3.6)

4. Defuzzyfication

The defuzzyfication step is conduted using the simplest, prevalent and physically appealing of all the defuzzyfication method, which is Centroid method. Centre of Gravity method is valid for symmetrical output membership functions, but have less computationally intensive. The crisp value of the output closeness rating model is:

$$CR = \frac{\sum_{i=1}^{r} \mu A(x) x(CR) Rr}{\sum_{i=1}^{r} \mu A(x)} \quad (3.7)$$

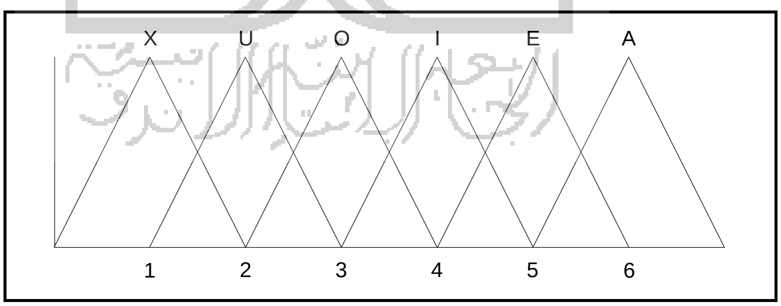


Figure 3.3 Representation of *(CR)*

3.2.3 CORELAP

The total closeness rating (TCR) used to determine the sequence of department that will be placed, the expression is:

$$TCR = \sum_{j=1, i\neq j}^{m} w_{ij} \tag{3.8}$$

3.3 Data Requirement

This research uses primary data collected from direct observation in the field. The data is focused on the PT. Fumira, especially in production department. The data is described as follow:

1. Initial layout
2. Department area and allowance
3. Material handling equipment cost
4. Material handling equipment type
5. Material flow between the machines in one shift
6. Equipment flow between the machines in one shift

3.4 Data Analysis

Data analysis is focused to comparing total cost flow in the initial layout with the new layout based on CARC that obtained from fuzzy set model. The parameter of optimize layout is that the new layout cost flow is lower than initial layout cost flow.

3.5 Analysis Tool

The analysis tool used in data analysis is using Microsoft Excel® to model the layout using CORELAP technique. Then the model is optimized with CRAFT using WinQSB® to obtain the minimal total cost flow of the initial and new layout.

3.6 Research Flow Diagram

The research steps are described in the figure below:

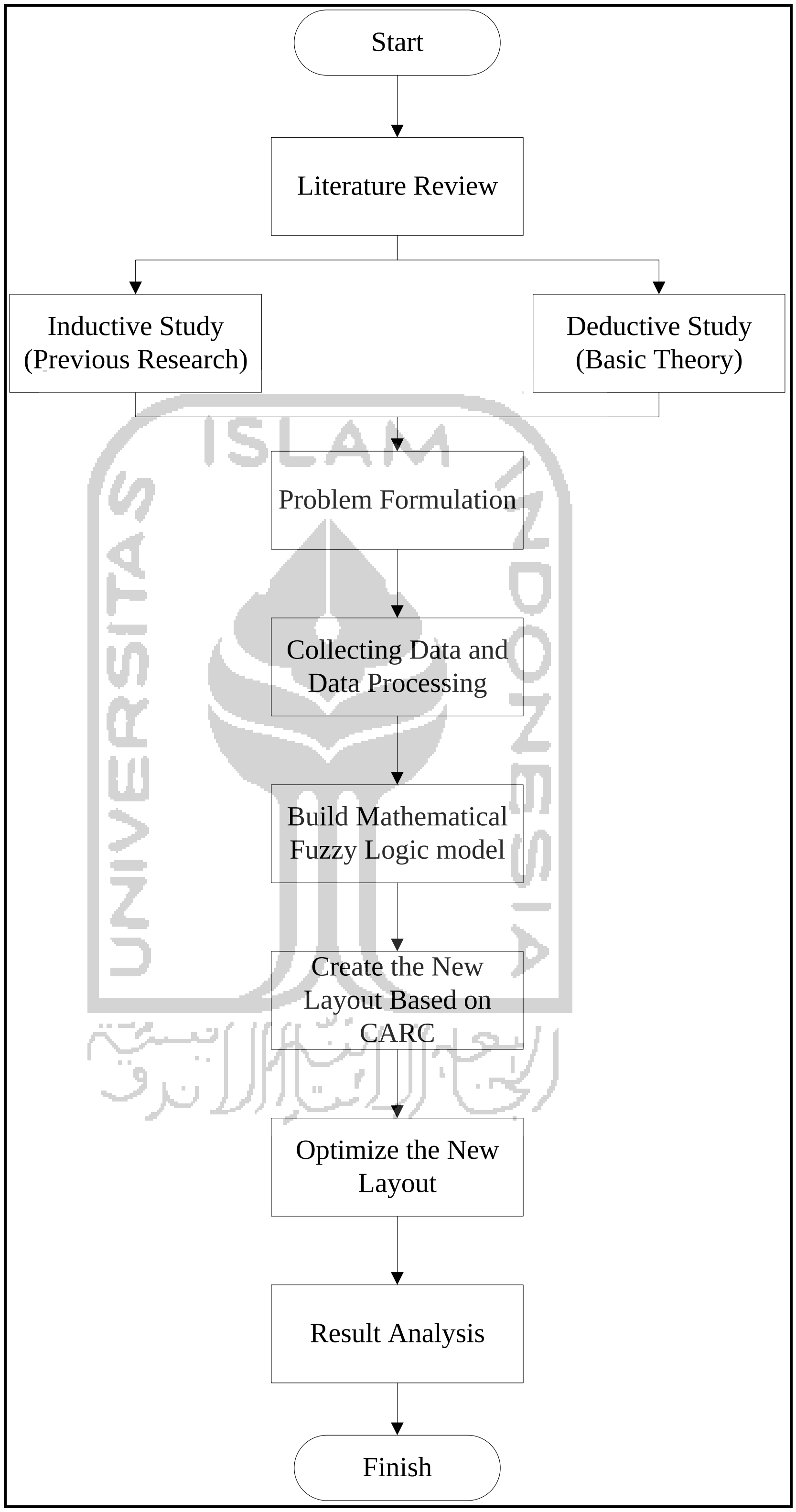


Figure 3.3 Research framework

CHAPTER IV

DATA COLLECTING AND DATA PROCESSING

4.1 Data Collecting

This research uses primary data collected from direct observation at PT. Fumira focused in the production department, taken from production data in Product Handling Department in May 2011. More detailed data will be explained in the following sub-chapter.

A. Initial Layout

The initial layout at Finishing Line Department in PT. Fumira is shown in figure below.

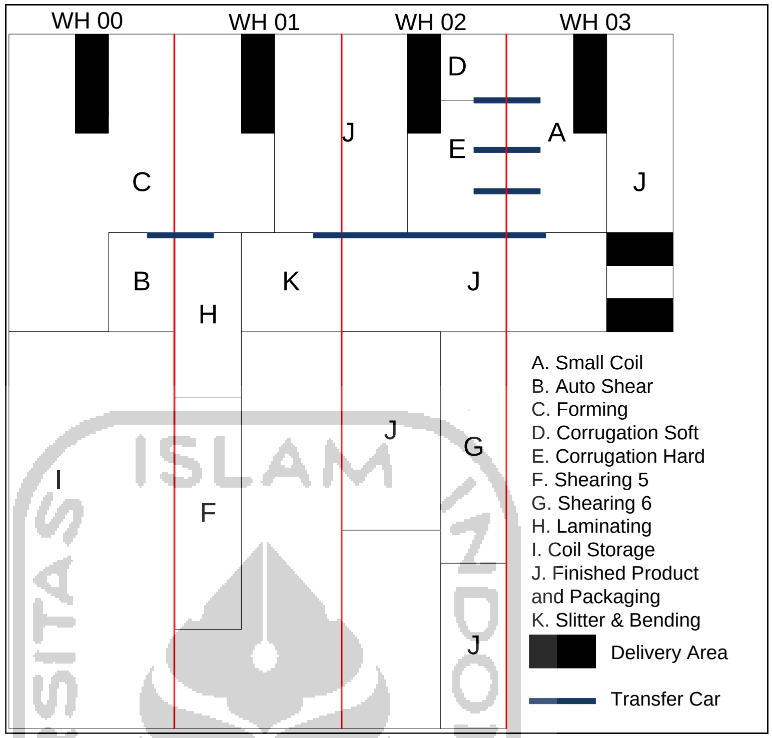


Figure 4.1 Initial Layout

B. Area

The areas of each machines/departments is shown in table below. The area including allowance.

Table 4.1 Area

No	Name	Area(m^2)	Location Fixed
A	Small Coil	648	No
B	Auto Shear	216	No
C	Forming	2084	No
D	Corrugation Soft	216	No
E	Corrugation Hard	432	No
F	Shearing-5	504	Yes
G	Shearing-6	504	Yes
H	Laminating	360	No
I	Coil Storage	4280	No
J	Packaging	3380	No
K	Slitter&Bending	324	No
	Delivery	324	Yes

C. Material Handling Equipment Cost

Material handling cost calculated by the cost that material handling equipment travelled per meter.

Table 4.2 Material Handling Cost

No	Name	Cost (Rp/m)
1	Crane	50
2	Forklift	80
3	Transfer Car	50
4	Manual TC	15

D. Material Handling Equipment Type

Material Handling Type data show what material handling equipment that used between the machines/departments.

Table 4.3 Material Handling Type

From	To	MH Equipment
Small Coil	Packaging	C
Auto Shear	Forming	C+MTC
Forming	Packaging	C
Corrugation Soft	Packaging	C+MTC+C
Corrugation Hard	Packaging	C+MTC+C
Shearing-5	Forming	C
	Corrugation Soft	F/C+TC+C+MTC+C
	Corrugation Hard	F/C+TC+C+MTC+C
	Packaging	F/C+TC+C
	Bending	C
Shearing-6	Corrugation	C+MTC+C

From	To	MH Equipment
	Hard	
	Packaging	F/C+TC+C
Laminating	Forming	C
Coil Storage	Small Coil	F/C+TC+C
	Auto Shear	C
	Shearing-5	C
	Shearing-6	C
	Laminating	C
	Packaging	C
Slitter & Bending	Packaging	C

C=Crane F=Forklift TC=Transfer Car MTC=Manual Transfer Car

E. Material Flow (MF)

The material flow *(MF)* is the material that flow between machines/departments in piece/shift. The data taken on May 2011.

Table 4.4 Material Flow

From	To	Material Flow
Small Coil	Packaging	1020
Auto Shear	Forming	1832
Forming	Packaging	2276
Corrugation Soft	Packaging	125
Corrugation Hard	Packaging	5000
Shearing-5	Forming	2966
	Corrugation Soft	1200
	Corrugation Hard	14516
	Packaging	6676
	Bending	76
Shearing-6	Corrugation Hard	18807
	Packaging	9326
Laminating	Forming	444
Coil Storage	Small Coil	1020
	Auto Shear	1832
	Shearing-5	25434
	Shearing-6	28133
	Laminating	444

From	To	Material Flow
	Packaging	480
Slitter & Bending	Packaging	76

F. Equipment Flow (EF)

Equipment Flow *(EF)* is the moving amount of material handling equipment between departments in one shift. The data taken on May 2011.

Table 4.5 Equipment Flow

From	To	Equipment Flow
Small Coil	Packaging	4
Auto Shear	Forming	8
Forming	Packaging	12
Corrugation Soft	Packaging	2
Corrugation Hard	Packaging	14
Shearing-5	Forming	7
	Corrugation Soft	6
	Corrugation Hard	28
	Packaging	17
	Bending	1
Shearing-6	Corrugation Hard	31
	Packaging	20
Laminating	Forming	2
Coil Storage	Small Coil	4
	Auto Shear	4
	Shearing-5	14
	Shearing-6	14
	Laminating	2
	Packaging	3
Slitter & Bending	Packaging	1

4.2 Data Processing

4.2.1 Mathematical and Fuzzy Modeling

A. Determining the Input and Output Variables

The input variables to be analyzed are *(MF)* and *(EF)* and the output is *(CR)* which will be used to determine the layout design.

B. Fuzzy Set and the Membership Function

Fuzzy set for *(MF)* and *(EF)* are shown in figures below.

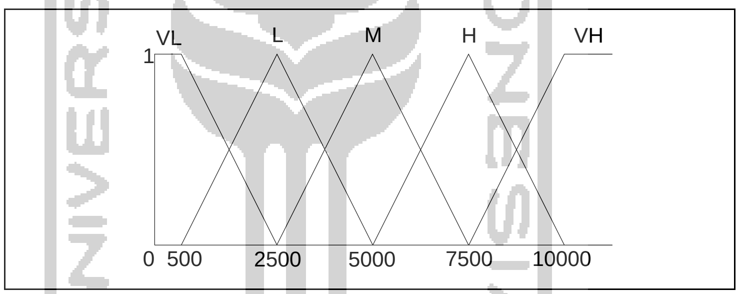


Figure 4.2 Representation of *(MF)*

Membership function:

$$\mu A\ VL\ (x) = \begin{cases} 0; & x \geq 2500 \\ 1; & x \leq 500 \\ 2500 - x/2500 - 500\,; & 500 \leq x \leq 2500 \end{cases} \tag{4.1}$$

$$\mu A\ L\ (x) = \begin{cases} 0; & x \leq 500 \\ x - 500/2500 - 500\,; & 500 \leq x \leq 2500 \\ 5000 - x/5000 - 2500\,; & 2500 \leq x \leq 5000 \\ 0; & x \geq 5000 \end{cases} \tag{4.2}$$

$$\mu A\ M\ (x) = \begin{cases} 0; & x \leq 2500 \\ x - 2500/5000 - 2500\ ; & 2500 \leq x \leq 5000 \\ 7500 - x/7500 - 5000\ ; & 5000 \leq x \ \leq 7500 \\ 0; & x \ \geq 7500 \end{cases} \quad (4.3)$$

$$\mu A\ H\ (x) = \begin{cases} 0; & x \leq 5000 \\ x - 5000/7500 - 5000\ ; & 5000 \leq x \leq 7500 \\ 10000 - x/10000 - 7500\ ; & 7500 \leq x \ \leq 10000 \\ 0; & x \ \geq 10000 \end{cases} \quad (4.4)$$

$$\mu A\ VH\ (x) = \begin{cases} 0; & x \leq 7500 \\ x - 7500/10000 - 7500\ ; & 7500 \leq x \leq 10000 \\ 1; & x \geq 10000 \end{cases} \quad (4.5)$$

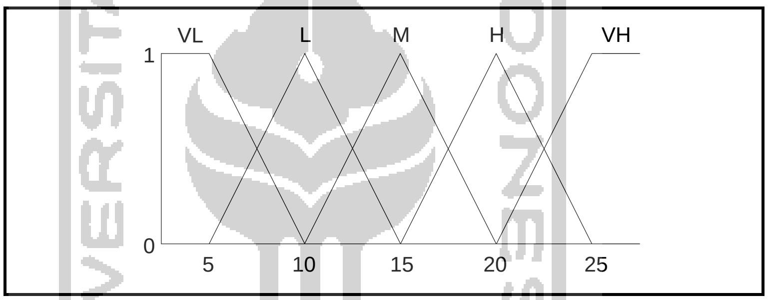


Figure 4.3 Representation of *(EF)*

Membership function:

$$\mu A\ VL\ (x) = \begin{cases} 0; & x \geq 10 \\ 1; & x \leq 5 \\ 10 - x/10 - 5\ ; & 5 \leq x \ \leq 10 \end{cases} \quad (4.6)$$

$$\mu A\ L\ (x) = \begin{cases} 0; & x \leq 5 \\ x - 5/10 - 5\ ; & 5 \leq x \leq 10 \\ 15 - x/15 - 10\ ; & 10 \leq x \ \leq 15 \\ 0; & x \ \geq 15 \end{cases} \quad (4.7)$$

$$\mu A\ M\ (x) = \begin{cases} 0; & x \leq 10 \\ x - 10/15 - 10\ ; & 10 \leq x \leq 15 \\ 20 - x/20 - 15\ ; & 15 \leq x \ \leq 20 \\ 0; & x \ \geq 20 \end{cases} \quad (4.8)$$

$$\mu A\ H\ (x) = \begin{cases} 0; & x \leq 15 \\ x - 15/20 - 15\,; & 15 \leq x \leq 20 \\ 25 - x/25 - 20\,; & 20 \leq x \ \leq 25 \\ 0; & x \ \geq 25 \end{cases} \quad (4.9)$$

$$\mu A\ VH\ (x) = \begin{cases} 0; & x \leq 20 \\ x - 20/25 - 20\,; & 20 \leq x \leq 25 \\ 1; & x \geq 25 \end{cases} \quad (4.10)$$

C. Fuzzy Rules

The numbers of rules for fuzzy inference system from combination of 2 variables are 25. The equation is shown below:

$$R_{(r)} = \text{IF } MF \text{ is } x \text{ AND } EF \text{ is } y \text{ THEN } CR = k \quad (4.11)$$

Where:

$R_{(r)}$= Rule number r

MF= Number of material flow

EF= Number of equipment flow

CR= Closeness rating value

x= Fuzzy universe of discourse of *MF*

y= Fuzzy universe of discourse of *EF*

k= Constant value as consequences

Since there are 6 parameters of output *(CR)*, the constant value need to be determined based on input range. Table 4.6 below show the constant value in each rule.

Table 4.6 Closeness Rating Value

RULE	MF	EF	CR
1	VL	VL	U
2	VL	L	U
3	VL	M	O
4	VL	H	I
5	VL	VH	I
6	L	VL	U
7	L	L	O
8	L	M	O
9	L	H	I
10	L	VH	I
11	M	VL	O
12	M	L	O
13	M	M	I
14	M	H	E
15	M	VH	E
16	H	VL	I
17	H	L	I
18	H	M	E
19	H	H	A
20	H	VH	A
21	VH	VL	I
22	VH	L	I
23	VH	M	E
24	VH	H	A
25	VH	VH	A

Based on the data collection, there are only 16 rules that necessary. They are Rule 1, 2, 3, 6, 7, 8, 11, 12, 13, 14, 18, 19, 22, 23, 24, 25.

D. Fuzzy Calculation

There are 20 relationships of departments that have *MF* and *EF* between the two departments. Each relationships will resulting *CR* as the output. More detailed data shown in Table 4.7:

Table 4.7 Relationship Data Between Departments

No	From	To	MF	EF
1	Small Coil	Packaging	1020	4
2	Auto Shear	Forming	1832	8
3	Forming	Packaging	2276	12
4	Corrugation Soft	Packaging	125	2
5	Corrugation Hard	Packaging	5000	14
6	Shearing-5	Forming	2966	7
7	Shearing-5	Corrugation Soft	1200	6
8	Shearing-5	Corrugation Hard	14516	28
9	Shearing-5	Packaging	6676	17
10	Shearing-5	Slitter&Bending	76	1
11	Shearing-6	Corrugation Hard	18807	31
12	Shearing-6	Packaging	9326	20
13	Laminating	Forming	444	2
14	Coil Storage	Small Coil	1020	4
15	Coil Storage	Auto Shear	1832	4
16	Coil Storage	Shearing-5	14000	14
17	Coil Storage	Shearing-6	14000	14
18	Coil Storage	Laminating	444	2
19	Coil Storage	Packaging	480	3
20	Slitter&Bending	Packaging	76	1

The data above then calculated using initial value of each parameter and based on fuzzy rules to obtain the *CR.* The fuzzy calculation is using software MATLAB® FIS Editor GUI. Here are the steps:

1. In FIS Editor Window, determine the input and output. In this case the inputs are MF and EF. Add the input by click on Edit->Add variable->Input.

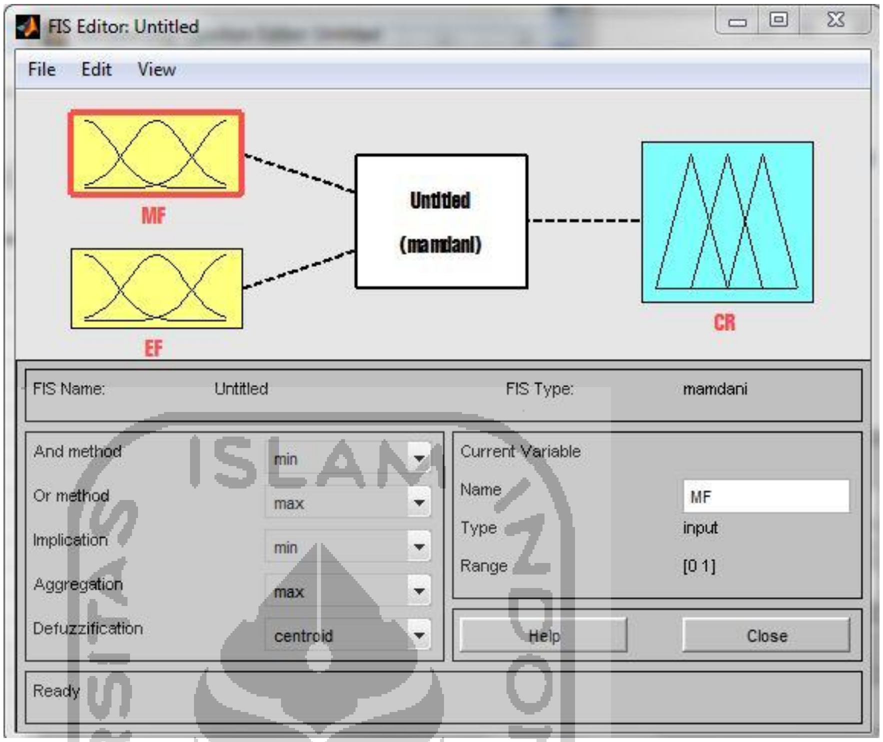


Figure 4.4 FIS Editor

2. Click on Edit->Membership Functions, and new window will appear. Edit the Membership Functions in each input and output. Determine the range first, and then add Membership Function by the number of Membership Function's needed. Add it by click on Edit->Add MF's. If the Membership Function type is trapezium, change it in Type column by trapmf type. Then determine the parameters in each Membership Function. Repeat the steps until finished.

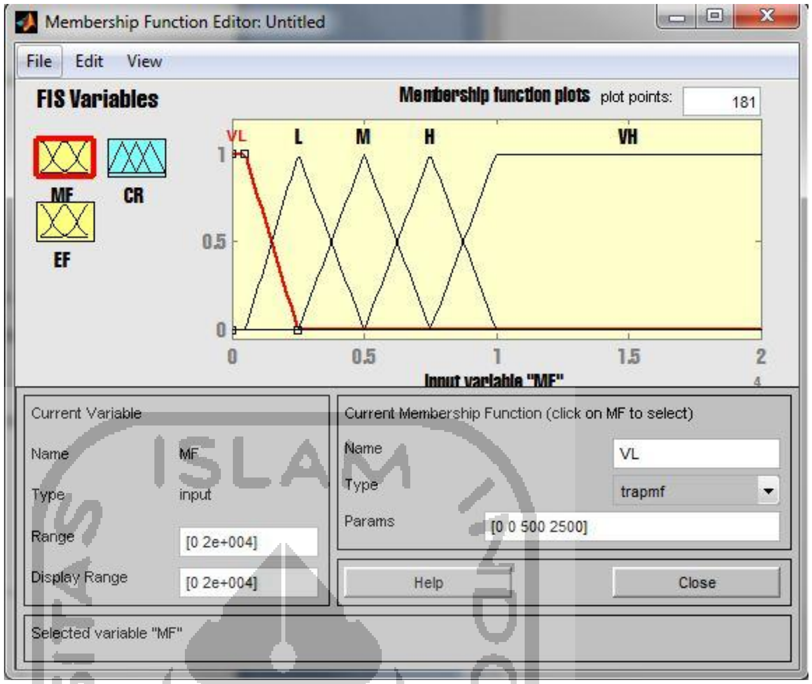


Figure 4.5 Membership Function Editor

3. Click on Edit->Rules to add the Rules. There are 16 rules, the connection is AND. Add the rules one by one.

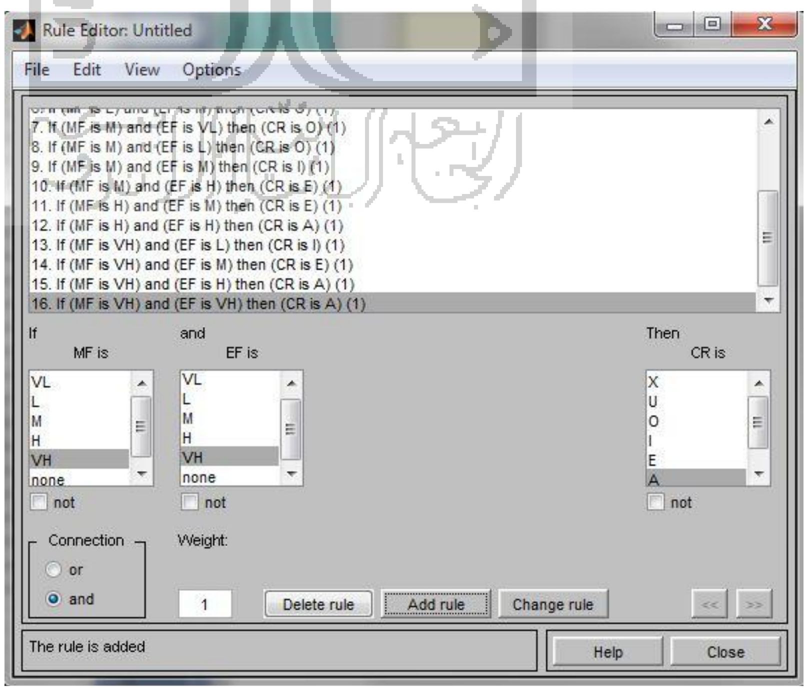


Figure 4.6 Rule Editor

4. After all rules have been added, click View->Rules, the new window will appear. Input the data into Input column, then the CR will be obtained.

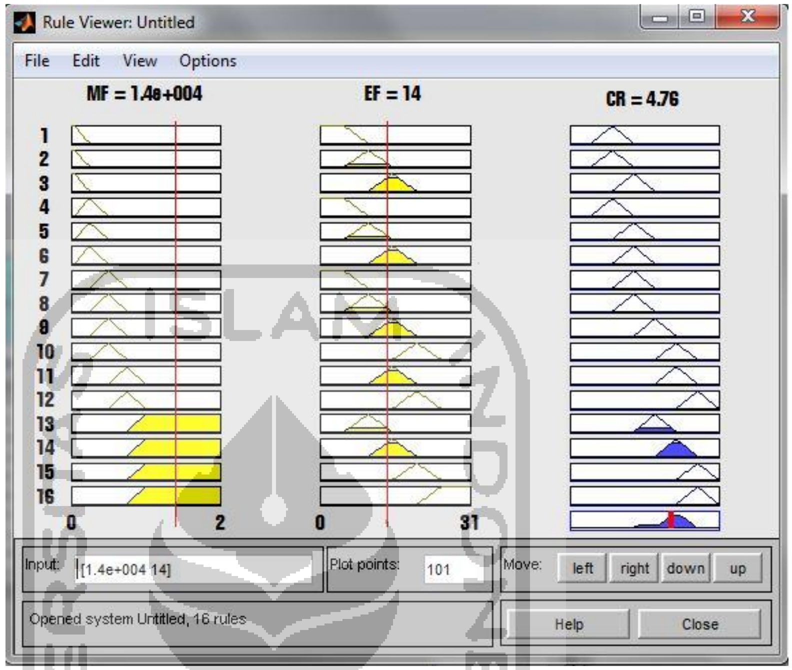


Figure 4.7 Rule Viewer

Based on summary of fuzzy calculation, *CR* are obtained. The *CR* between the departments then become Crisp Activity Relationship Chart.

Table 4.8 Crisp Avtivity Relationship Chart

Dept	A	B	C	D	E	F	G	H	I	J	K
A		2	2	2	2	2	2	2	2	2	2
B	2		2,58	2	2	2	2	2	2,26	2	2
C	2	2,58		2	2	2,42	2	2	2	2,83	2
D	2	2	2		2	2,26	2	2	2	3	2
E	2	2	2	2		6	6	2	2	3,76	2
F	2	2	2,42	2,26	6		2	2	4,76	5,05	2
G	2	2	2	2	6	2		2	4,8	6	2
H	2	2	2,25	2	2	2	2		2	2	2
I	2	2,26	2	2	2	4,8	4,8	2,25		2	2
J	2	2	2,83	2	3,76	5,05	6	2	2		2
K	2	2	2	2	2	2	2	2	2	2	

4.2.2 CORELAP

4.2.2.1 Total Closeness Rating

Total Closeness Rating (TCR) based on Crisp Activity Relationship Chart shown in table below:

Table 4.9 Total Closeness Rating

Dept	Name	TCR	Order
A	Small Coil	20	11
B	Auto Shear	20.58	7
C	Forming	21.83	6
D	Corrugation Soft	20.26	8
E	Corrugation Hard	29.76	4
F	Shearing-5	30.49	2
G	Shearing-6	30.76	1
H	Laminating	20	10
I	Coil Storage	25.52	5
J	Packaging	29.64	3
K	Slitter & Bending	20	9

4.2.2.2 Placement Sequence

The placement of the departments in the layout based on TCR is G-F-J-E-I-C-B-D-K-H-A. More detailed steps of placement of the departments described as follow :

a. Placement Sequence: **G-F**-J-E-I-C-B-D-K-H-A

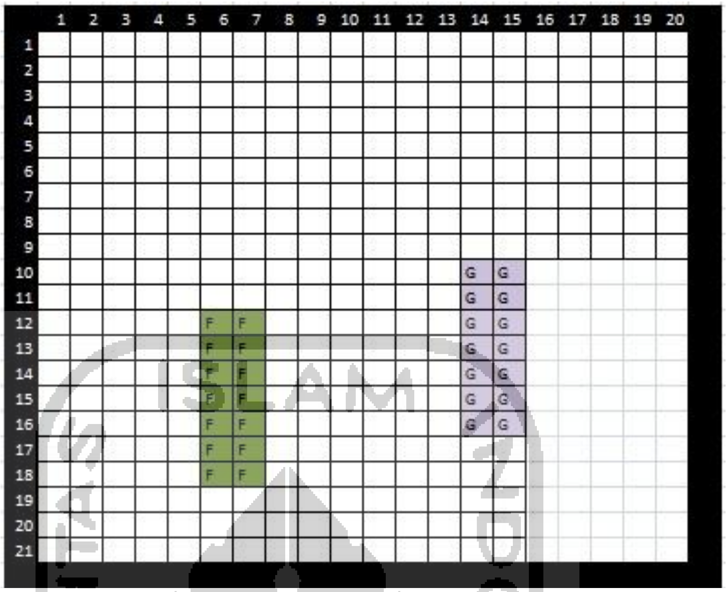


Figure 4.8 CORELAP Step 1

b. Placement Sequence: G-F-**J**-E-I-C-B-D-K-H-A

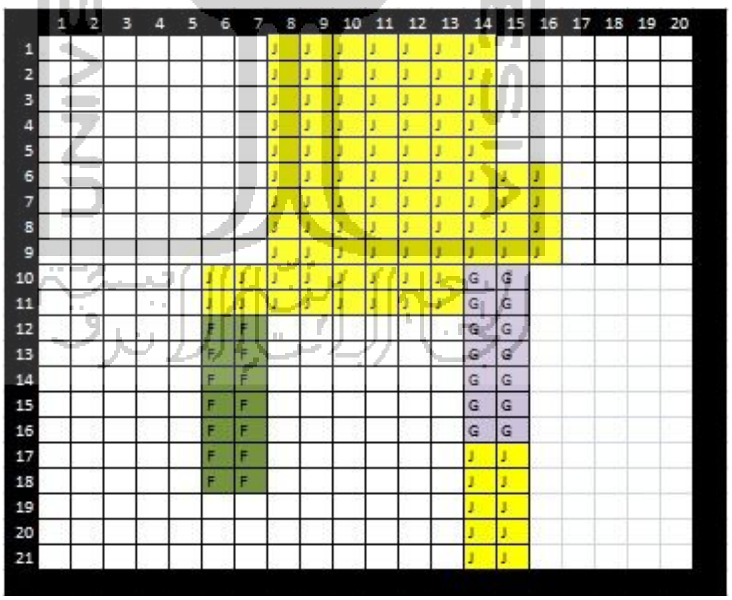


Figure 4.9 CORELAP Step 2

c. Placement Sequence: G-F-J-**E**-I-C-B-D-K-H-A

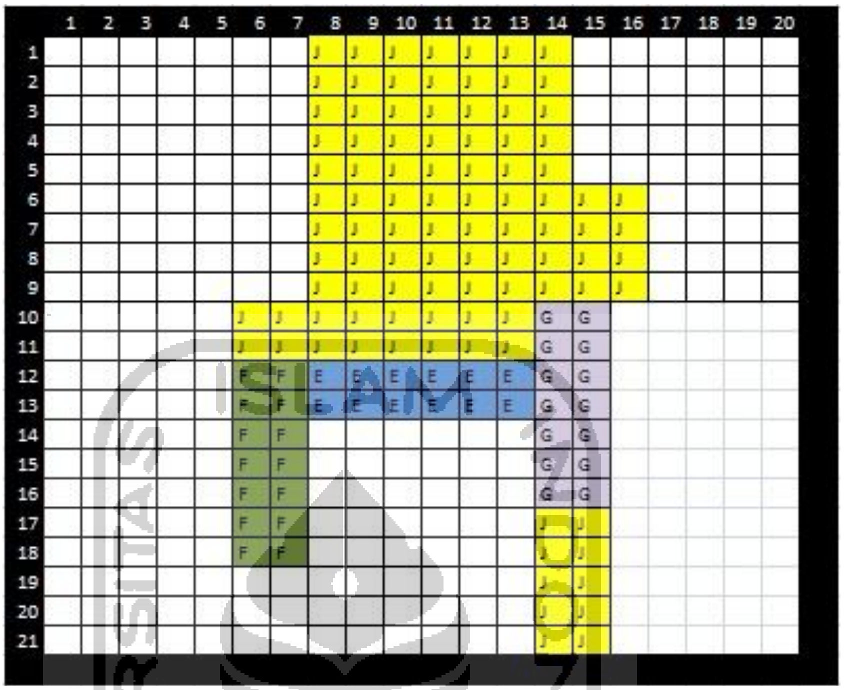


Figure 4.10 CORELAP Step 3

d. Placement Sequence: G-F-J-E-**I**-C-B-D-K-H-A

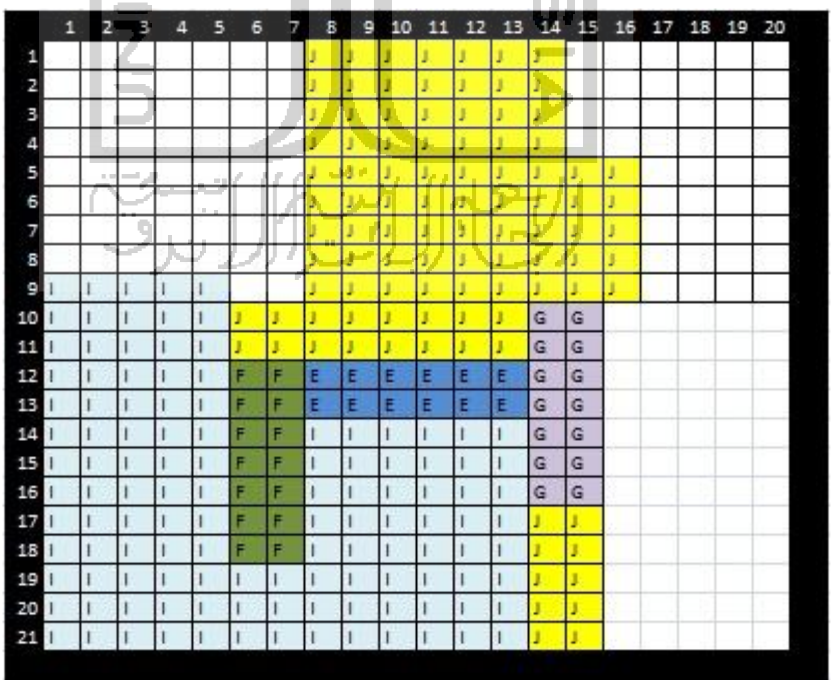


Figure 4.11 CORELAP Step 4

e. Placement Sequence: G-F-J-E-I-**<u>C</u>**-B-D-K-H-A

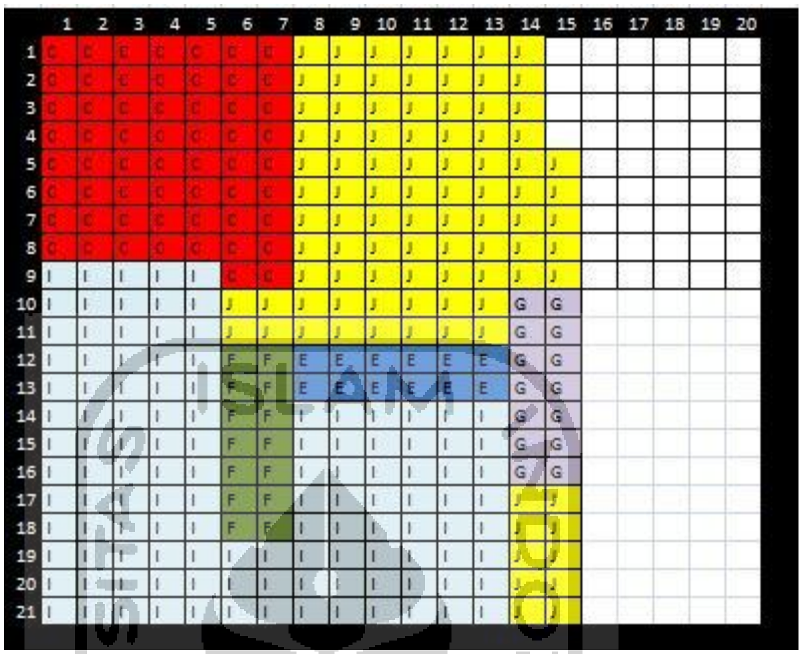


Figure 4.12 CORELAP Step 5

f. Placement Sequence: G-F-J-E-I-C-**<u>B-D</u>**-K-H-A

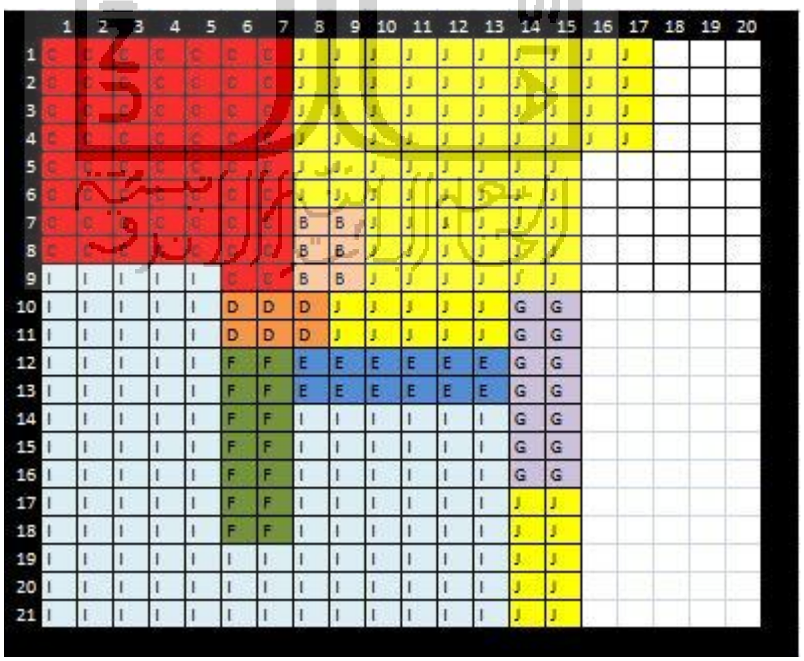


Figure 4.13 CORELAP Step 6

g. Placement Sequence: G-F-J-E-I-C-B-D-**K-H**-A

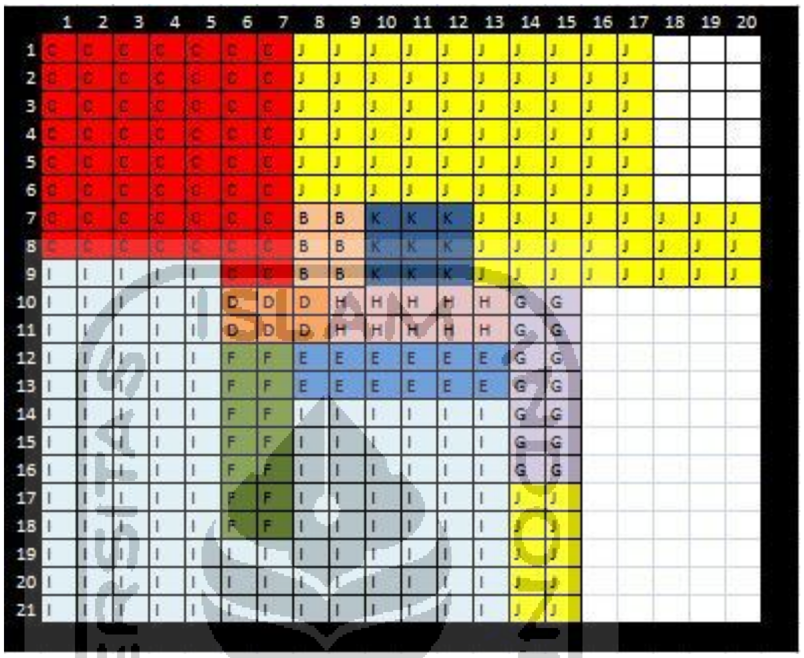


Figure 4.14 CORELAP Step 7

h. Placement Sequence: G-F-J-E-I-C-B-D-K-H-**A**

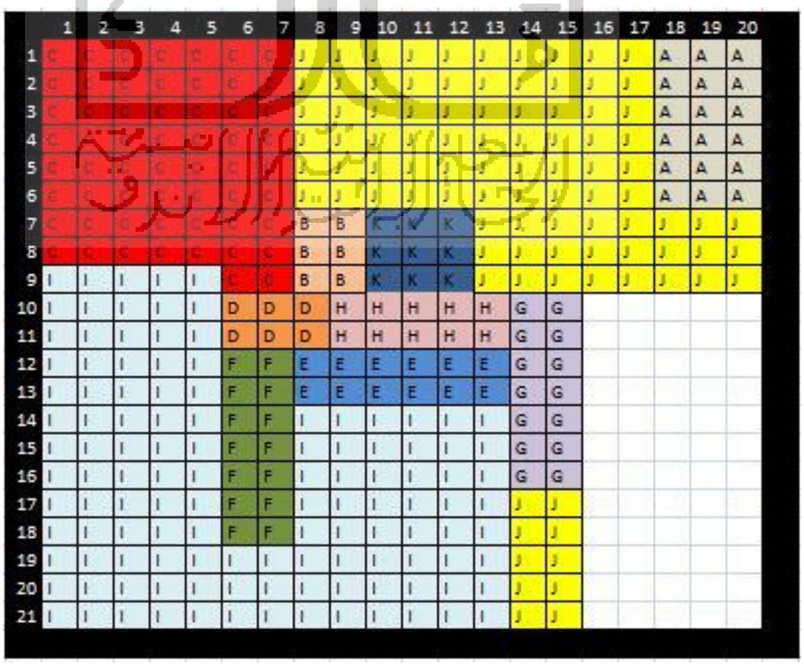


Figure 4.15 CORELAP Final Step

4.2.3 CRAFT

4.2.3.1 Material Handling Cost

Material handling cost between departments must be known to calculate the flow cost of the layout. Material handling cost obtained from Equipment Flow *(EF)* times by material handling equipment cost. Table 4.11 and 4.12 below show the material handling cost per shift.

Table 4.10 Material Handling Cost

From	To	Material Flow	Equipment Flow	MH Equipment	MH Cost (Rp/m)	MH Cost
Small Coil	Packaging	1020	4	C	50	200
Auto Shear	Forming	1832	8	C+MTC	65	520
Forming	Packaging	2276	12	C	50	600
Corrugation Soft	Packaging	125	2	C+MTC+C	32,5	65
Corrugation Hard	Packaging	5000	14	C+MTC+C	32,5	455
Shearing-5	Forming	2966	7	C	50	350
	Corrugation Soft	1200	6	F/C+TC+C+MTC+C	80	480
	Corrugation Hard	14516	28	F/C+TC+C+MTC+C	80	2240
	Packaging	6676	17	F/C+TC+C	80	1360
	Bending	76	1	C	50	50
Shearing-6	Corrugation Hard	18807	31	C+MTC+C	38,3333	1188,332
	Packaging	9326	20	F/C+TC+C	80	1600
Laminating	Forming	444	2	C	50	100
Coil Storage	Small Coil	1020	4	F/C+TC+C	80	320
	Auto Shear	1832	4	C	50	200
	Shearing-5	25434	14	C	50	700
	Shearing-6	28133	14	C	50	700
	Laminating	444	2	C	50	100
	Packaging	480	3	C	50	150
Slitter & Bending	Packaging	76	1	C	50	50

Table 4.11 Matrix of Material Handling Cost

		To	Small Coil	Auto Shear	Forming	Corrugation Soft	Corrugation Hard	Shearing-5	Shearing-6	Laminating	Coil Storage	Packaging	Slitter&Bending
			A	B	C	D	E	F	G	H	I	J	K
From													
Small Coil	A											200	
Auto Shear	B				520								
Forming	C											600	
Corrugation Soft	D											65	
Corrugation Hard	E											455	
Shearing-5	F				350	480	2240					1360	50
Shearing-6	G						1188,332					1600	
Laminating	H				100								
Coil Storage	I		320	200				700	700	100		150	
Packaging	J												
Slitter&Bending	K											50	

4.2.3.2 Cell Layout

From the initial layout developed by CORELAP, it must be converted into cell layout using Microsoft Excel to determine the coordinate of each departments. Each cell is represented of 6m x 6m area. Figure below show the cell layout based on initial layout:

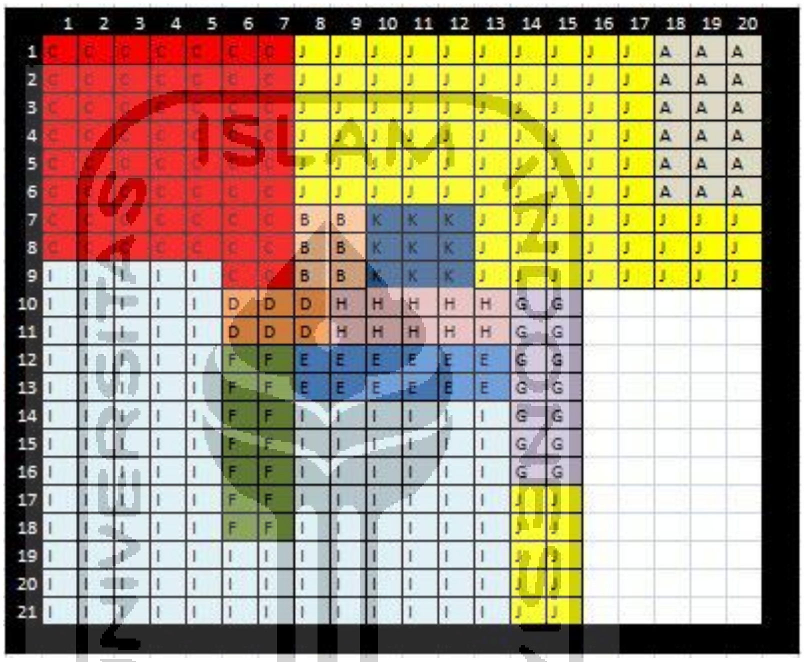


Figure 4.16 CORELAP Initial Cell Layout

From the initial cell layout developed using CORELAP, the coordinate of each departments can be determined. Table 4.12 below the coordinate of each deparments.

Table 4.12 Coordinates

Department	Name	Area (m2)	Coordinate
A	Small Coil	648	(1,18)-(6,20)
B	Auto Shear	216	(7,8)-(9,9)
C	Forming	2084	(1,1)-(8,7),(9,6)-(9,7)
D	Corrugation Soft	216	(10,6)-(11,8)
E	Corrugation Hard	432	(12,8)-(13,13)
F	Shearing-5	504	(12,6)-(18,7)

Department	Name	Area (m2)	Coordinate
G	Shearing-6	504	(10,14)-(16,15)
H	Laminating	360	(10,9)-(11,13)
I	Coil Storage	4280	(9,1)-(21,5),(19,6)-(21,7),(14,8)-(21,13)
J	Packaging	3380	(1,8)-(6,17),(7,13)-(9,20),(17,14)-(21,15)
K	Slitter & Bending	324	(7,10)-(9,12)

4.2.3.3 CRAFT Process

CRAFT process use software WinQSB® to ease the switches of departments and calculate the flow cost of the layout. The method used in this CRAFT is exchange between 2 departments. In analyse the improved layout, it must be considered the feasibility of the layout itself. More detailed steps of WinQSB will be explained below:

1. Preparation

   This step is the preparation before the CRAFT process can be ran, the project type is Functional Layout and the objective is minimization. The input are project name, number of departments, number of rows, and number of columns.

   Fill the project name, number of departments is 11, number of rows and columns based on initial cell layout developed using CORELAP are 20 and 21 respectively. Because the objective of this paper is to minimize the flow cost, choose minimization in objective criterion.

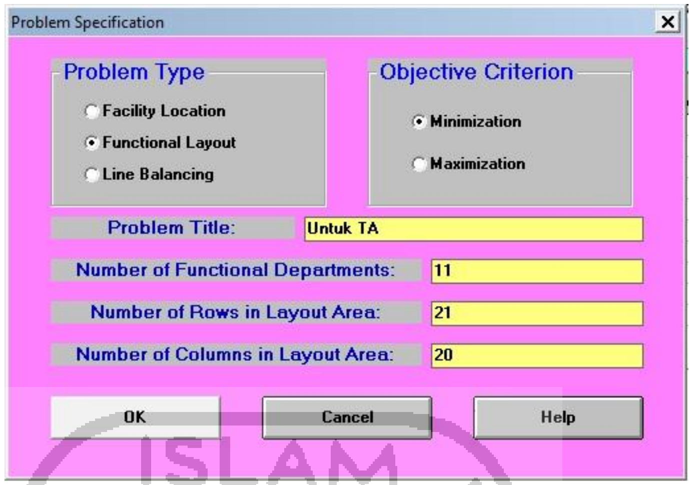


Figure 4.17 Problem Specification

2. Data Input

The data input in this step are department name, fixed location, flow cost, and the coordinate of departments. The department that have fixed location are department F (Shearing-5) and department G (Shearing-6), change the fixed location row of those two departments with Yes. Copy the material handling cost matrix into flow cost columns, and copy the coordinates in the Cell Locations.

Department Number	Department Name	Location Fixed	To Dep. 1	To Dep. 2	To Dep. 3	To Dep. 4	To Dep. 5	To Dep. 6	To Dep. 7	To Dep. 8	To Dep. 9	To Dep.	To Dep.	Initial Layout in Cell Locations [e.g., (3,5), (1,1)-(2,4)]
1	A	No										100		(1,18)-(6,20)
2	B	No			130									(10,6)-(11,8)
3	C	No										150		(1,1)-(8,7),(9,6)-(9,7)
4	D	No										32,5		(7,19)-(9,20)
5	E	No										162,5		(12,8)-(13,13)
6	F	Yes			150	160	1200					560	50	(12,6)-(18,7)
7	G	Yes					!8,3327					800		(10,14)-(16,15)
8	H	No			50									(10,9)-(11,13)
9	I	No	160	100				1300	1450	50		50		9,1)-(21,5),(19,6)-(21,7),(14,8)-(21,13)
10	J	No												1,8)-(6,17),(7,8)-(9,15),(17,14)-(21,15)
11	K	No										50		(7,16)-(9,18)

Figure 4.18 Data Input

3. Solve and Analyze

Make sure that the data inputted correctly, the click Slove and Analyze in the main menu window and choose Solve the Problem.

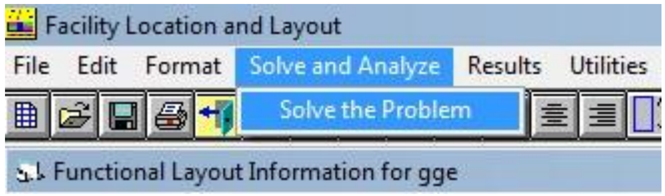


Figure 4.19Solve and Analyze

In Functional Layout Solution window, choose Improve by Exchanging 2 departments, Rectilinear Distance for Distance Measure and check Show the Exchange Iteration. Then, the CRAFT will estimate the layout change using this expression:

$$\sum_{k=1,k\neq i,k\neq j}^{n} f_{ik}\, d_{ik} + \sum_{k=1,k\neq i,k\neq j}^{n} f_{jk}\, d_{jk} - \sum_{k=1,k\neq i,k\neq j}^{n} f_{jk}\, d_{ik} - \sum_{k=1,k\neq i,k\neq j}^{n} f_{ik}\, d_{jk} \qquad (4.12)$$

Where d_{ij} and f_{ij} refer to the distance and flow between facilities *i* and *j*, respectively.

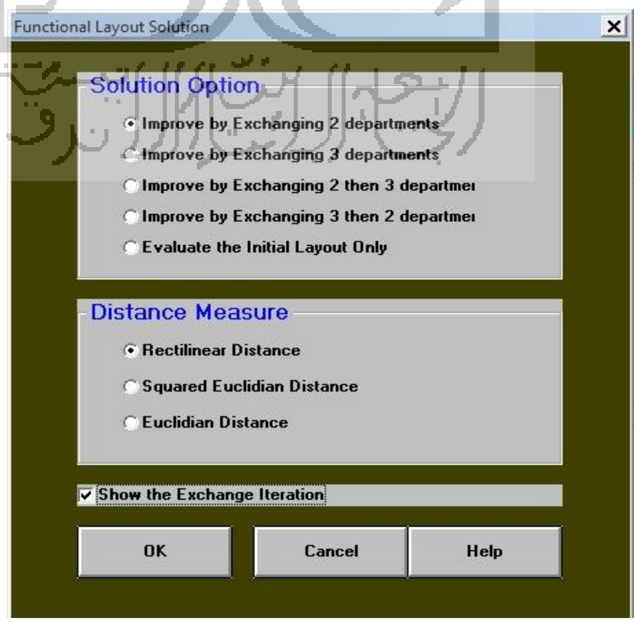


Figure 4.20 Functional Layout Solution

4. Output

The CRAFT process in exchanging 2 departments resulted 8 iterations of new layout, and also calculated the total flow cost from each layout. Each iteration must be analyzed whether its layout feasible or not. Then the final layout cost flow compared to initial layout.

Figures below show the layout and total cost flow from initial layout until last iterations:

a. Initial Layout

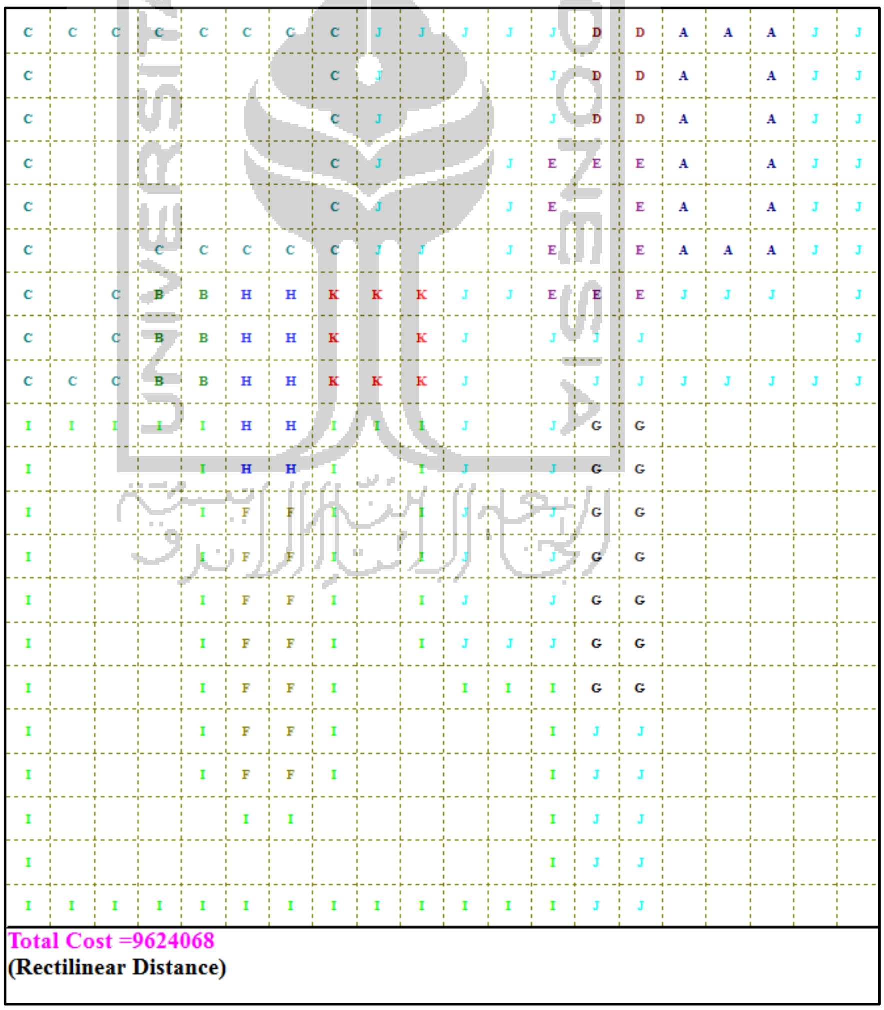


Figure 4.21 Initial Layout

b. Initial Layout developed using CORELAP

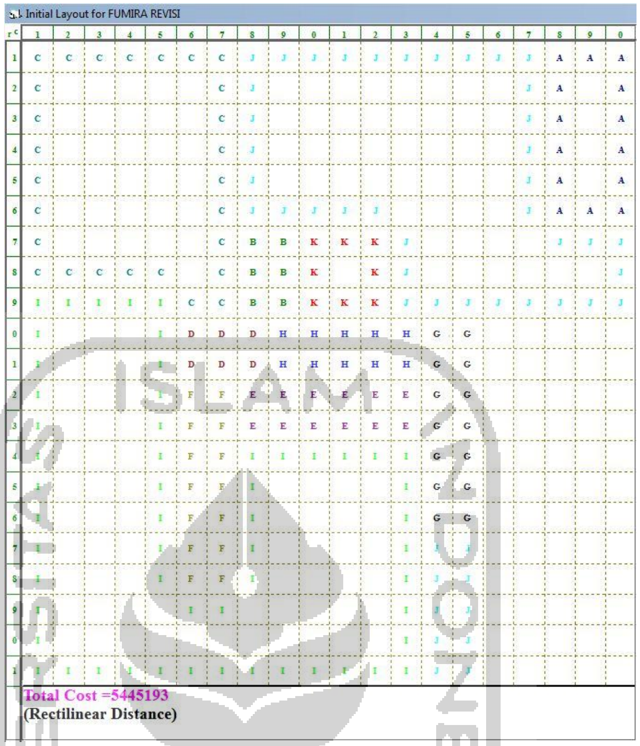


Figure 4.22 Initial Layout developed using CORELAP

c. First and Second Iteration

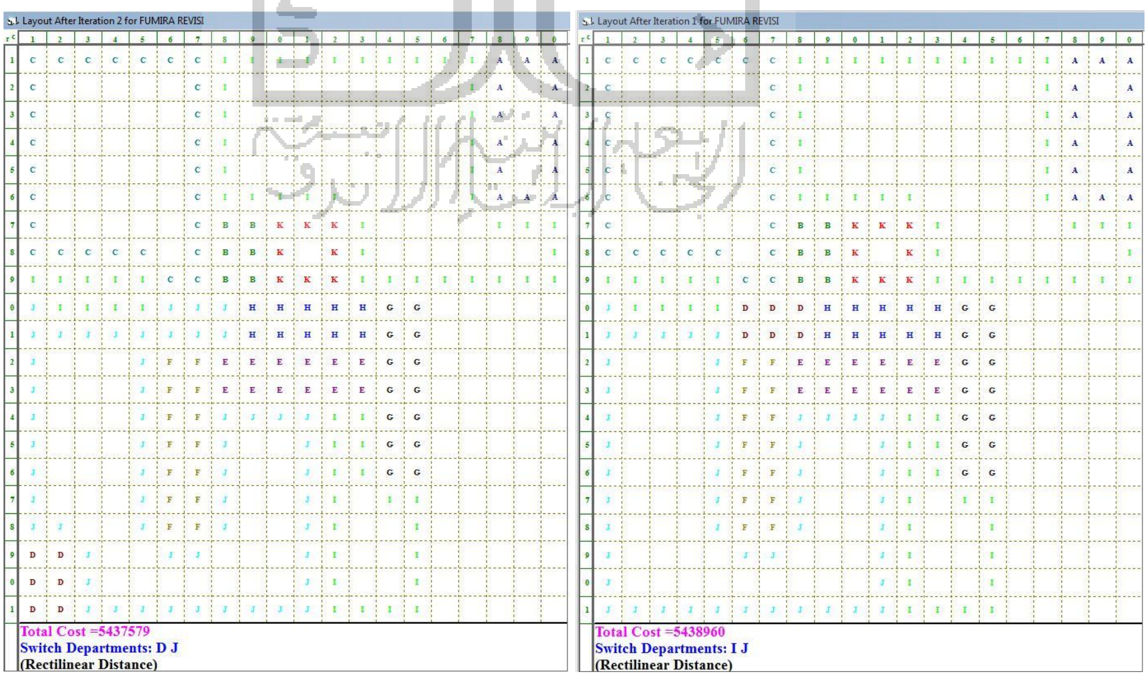


Figure 4.23 First Iteration (left) and Second Iteration (right)

d. Third and Fourth Iteration

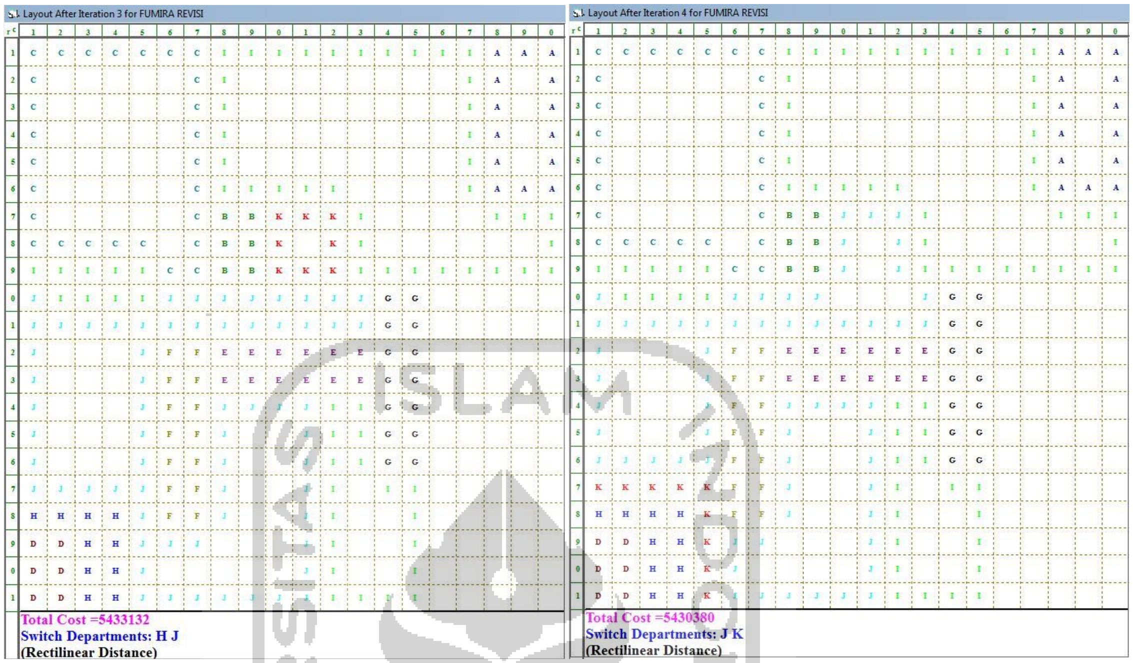


Figure 4.24 Third Iteration (left) and Fourth Iteration (right)

e. Fifth and Sixth Iteration

Figure 4.25 Fifth Iteration (left) and Sixth Iteration (right)

f. Seventh Iteration

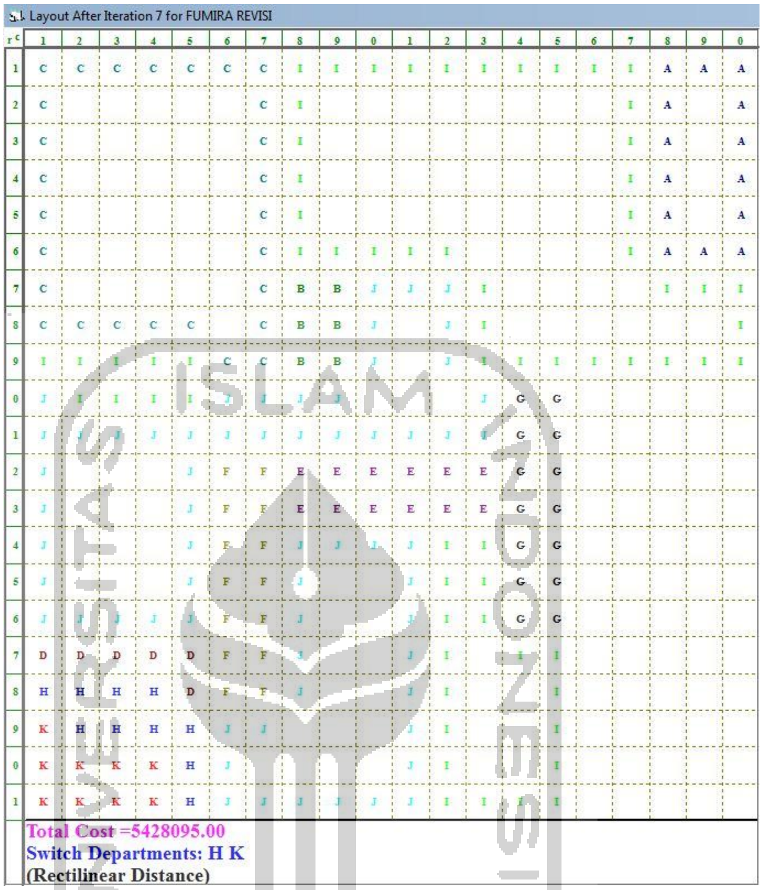


Figure 4.26 Seventh Iteration

Based on the iterations analysis and assumption, the CRAFT exchange between departments are not feasible from the first iteration, so it is means that the layout developed by CORELAP technique already good.

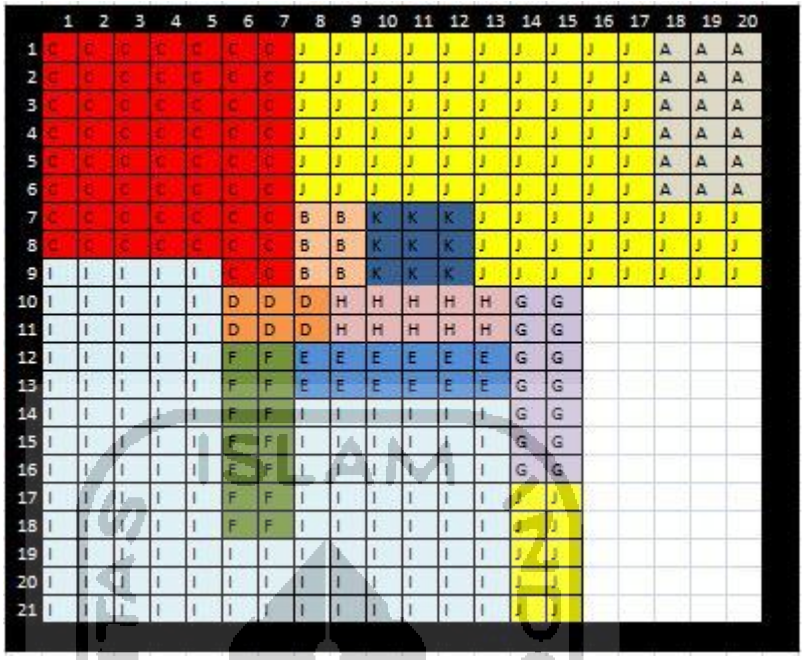


Figure 4.27 Final Layout

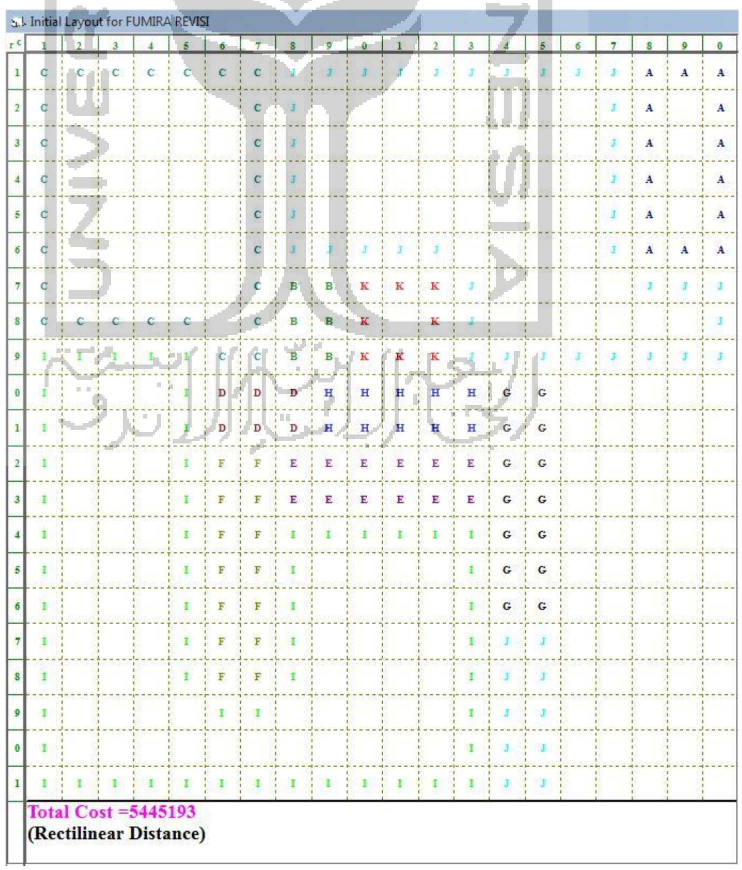


Figure 4.28 Final Layout Cost Flow

From the figures above, the layout design can be draw. Note that some supporting facilities also changed following the layout changes. In this case, the transfer car that located in the area of Corrugating moved into the new location of Corrugating.

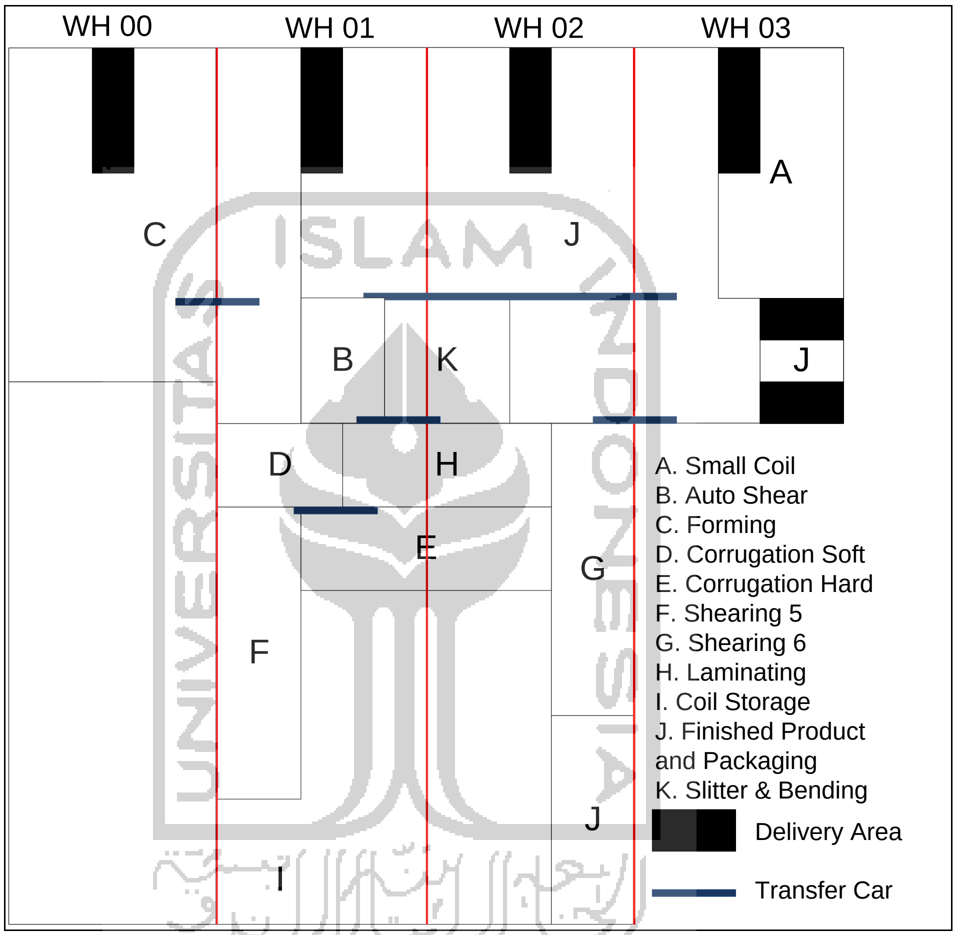


Figure 4.29 Final Layout

4.3 Summary

As seen on Figure 4.28, the total cost flow is Rp 5.445.193,00 per shift, reduced from Rp Rp 9.624.068,00 total cost flow in Initial Layout (Figure 4.16). The CRAFT processes are not feasible, so it the most optimal layout is in the final CORELAP layout.

CHAPTER V

DISCUSSION

As mentioned before, facility layout planning is important things in manufacture. Mostly, material handling is the main factor that affects the cost in facility layout. The material handling cost itself can be reduced by developing the new layout based on Crisp Activity Relationship Chart (CARC). As the purpose of this research, total cost flow of new developed layout reduced to 43%.

Fuzzy logic used to determine the amount for CARC based on variables and fuzzy rule. The variables used in this paper are Material Flow *(MF)* and Equipment Flow *(EF)*. CARC resulted various amount between departments that have relationship that used to the next process. CARC used to develop the new layout using CORELAP algorithm, using the Total Closeness Rating then from the final CORELAP layout, it optimized using CRAFT. Besides that, CRAFT also used to obtain the total flow cost the layout. The new developed layout switch some departments that have no fixed position and have similar areas into more profitable location. The switched departments also consider some factors and still need to be analyzed whether it is feasible or not.

5.1 Fuzzy Modeling

In fuzzy modeling there are two inputs to be analyzed, which are Material Flow *(MF)* and Equipment Flow *(EF)*, and the output is Closeness Rating *(CR)* which later used to create CARC. The fuzzy itself using Mamdani model. Based on combination of linguistic variables in each input, the number of fuzzy rule is 25. The fuzzy rules reduced from 25 rules in to 16 rules, based on the data collection the other 9 rules are not suit the data. Fuzzy rule can effect the output or not, it based on membership value in each rule. The membership value is between 0 and 1, the bigger membership value, the bigger effect of the rule to the output. Otherwise, membership value 0 is mean that the rule does not have any effect to the output. The 25 membership value then center-weighted using Center of Gravity method to obtain the crisp output, which is *CR*. In this research, there are 20 inputs that have relationship between departments and have both *MF* and *EF*.

5.2 CORELAP

CORELAP process start after the CARC obtained by fuzzy logic. CARC resulted Total Closeness Rating (TCR) which used to determine the sequence of department placement in CORELAP process. The sequence is : G-F-J-E-I-C-B-D-K-H-A (Shearing-5 and Shearing 6, beside it has bigger TCR, it also fixed location, then Packaging, Corrugation Hard, Coil Storage, Forming, Auto Shear, Corrugation Soft, Slitter & Bending, Laminating, and Small Coil respectively.

Calculated using WinQSB®, the total cost flow of material handling itself reduced to Rp 5. 445.193,00 from Rp 9.624.068,00 total cost flow in initial layout. Figure 5.1 show the final layout developed by CORELAP.

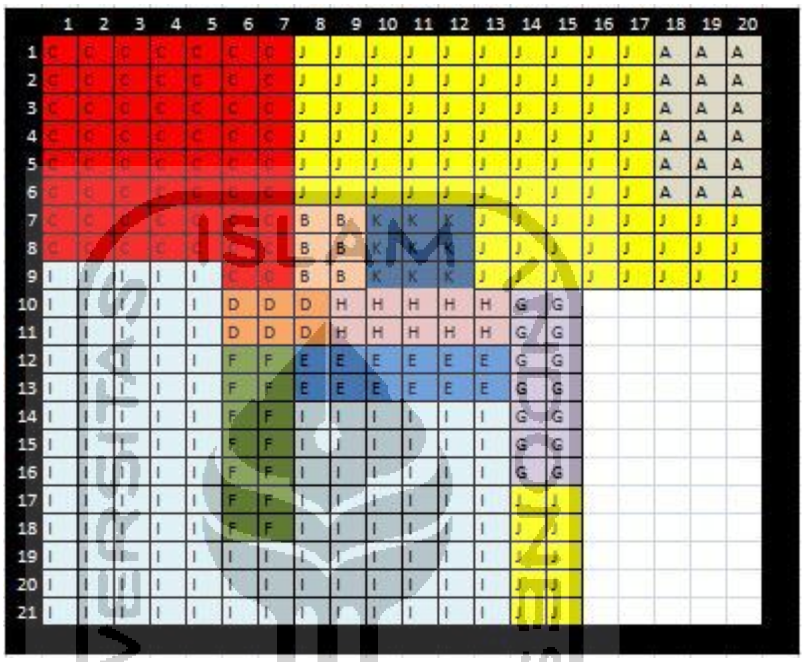


Figure 5.1 CORELAP Final Layout

5.3 CRAFT

To maximize the layout, CRAFT ran using software WinQSB®. In this research, CRAFT resulted 8 iterations of switched department, but still need to be analyzed. CRAFT also used to obtain the total flow cost of the layout. From the first iteration of the CRAFT process, it is not feasible anymore, because the departments of Packaging and Coil Storage are switched, but the Packaging area should near the Delivery area, which is located mainly in the top of the layout. Also in the next iterations, the Corrugation Soft switched into the bottom left of the layout, which is too far away from other production area.

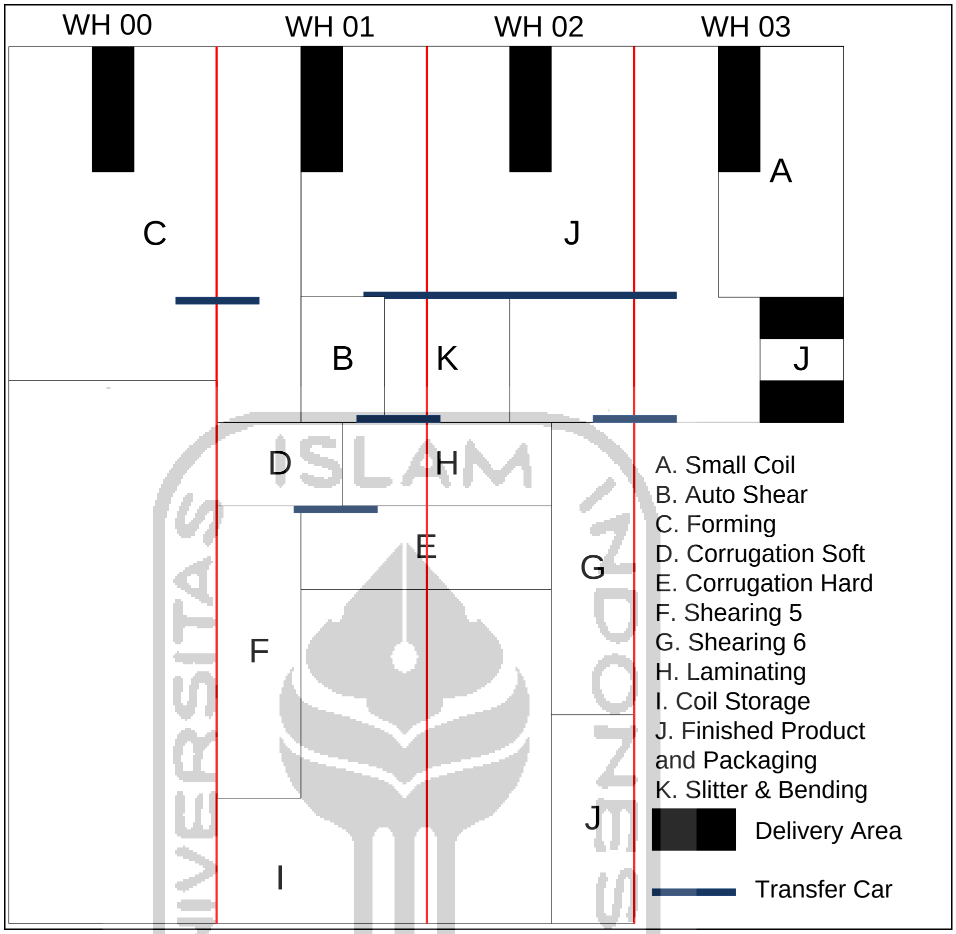


Figure 5.2 Final Layout

CHAPTER VI

DISCUSSION

6.1 Conclusion

The conclusion of this research can be established as follow:

a. Crisp Activity Relationship Chart (CARC) has resulted more optimize layout rather than traditional Activity Relationship Chart. To obtain CARC, fuzzy logic used to resulted crisp output which is Closeness Rating *(CR)* based on two inputs Material Flow *(MF)* and Equipment Flow *(EF)*, and also fuzzy rule. According to CARC, new layout can be developed using CORELAP algorithm and CRAFT to optimize the layout.

b. The material handling cost in new developed layout is Rp 5. 445.193,00 per shift, reduced from Rp 9.624.068,00 per shift in initial layout. The optimize layout can be seen on Figure 5.2 in chapter five.

6.2 Recommendation

Some recommendations in this research described as follow:

a. According to the result of this research, company can consider this layout to reduce the cost in manufacturing their product. Moreover, using this fuzzy logic to determine the CARC is more objective rather than traditional ARC, and resulted more minimize material handling cost.

b. Further research can implement this method to developing new layout, or maximize the recent layout by minimize the material handling cost. Beside *MF* and *EF*, more inputs can be considered. ALDEP algorithm also can be implemented, except of CORELAP.

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