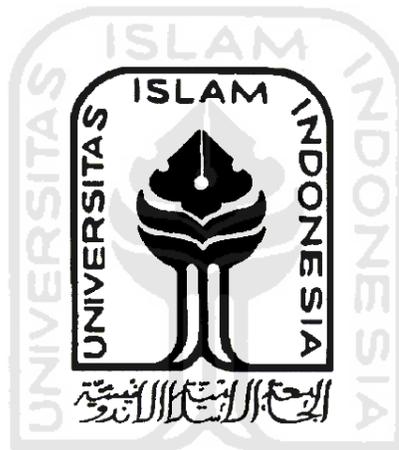


**REVIEW OF ATTRACTORS-REPELLER APPROACH  
FOR FACILITY LAYOUT DESIGN**

(Case study at PT. Solo Grafika Utama)

Thesis

Submitted to International Program  
Faculty of Industrial Technology in partial fulfillment of  
Requirement for the degree of Sarjana Teknik Industri  
Universitas Islam Indonesia



By:

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No : 06 522 113

**INTERNATIONAL PROGRAM  
INDUSTRIAL ENGINEERING DEPARTMENT  
FACULTY OF INDUSTRIAL TECHNOLOGY  
UNIVERSITAS ISLAM INDONESIA  
YOGYAKARTA  
2011**

**SUPERVISOR APPROVED RATIFICATION**

**REVIEW OF ATTRACTORS-REPELLER APPROACH  
FOR FACILITY LAYOUT DESIGN**

(Case study in PT. Solo Grafika Utama)

**THESIS**



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A handwritten signature in black ink, which appears to be 'Chairul Saleh', is written over a horizontal line. The signature is stylized and cursive.

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**REVIEW OF ATTRACTORS-REPELLER APPROACH  
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(Case study in PT. Solo Grafika Utama)

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## DEDICATION PAGE

*This work is dedicated to my beloved family*

*My Mother with her endless love, that put the seed of humanity in me.*

*My Father with his outstanding sacrifice, real Basukarna for my life that raise me to a big dream.*

*My little brother with his magical smile, we are tigers.*



## MOTTO

*“Khairunnas anfa'uhum lin nas”*

*"The best among you is the one who benefits the others."*

*"Bhinneka Tunggal Ika, Tan Hana Dharma Magrwa"*

*"Diversity remain unify, no truth is ambiguous”*



## FOREWORDS

*Assalamu 'alaikum Wr. Wb.*

Alhamdulillahirobill'alamiin, praise the presence of Allah SWT who has given His guidance, opportunities, and ease in carrying out this mandate so that this thesis can be resolved. Sholawat and salam may always devoted to the Prophet Muhammad SAW, noble inspiration of morals and personal character.

This thesis composed as partial fulfilment of Requirement for the degree of Sarjana Teknik Industri of Universitas Islam Indonesia. As for the title that I took was "Facility Layout Improvement Using Attractor Repeller Approach". This research took a problem at PT. Solo Grafika Utama as the case study.

It is impossible for the author to finish the thesis alone. The author very appreciates for the support, for the suggestion given to make this work better, and for the verification that make it perfect. That's why the author would like to thanks to:

1. Prof. Dr. Ir. R. Chairul Saleh, M.Sc., as supervisor for his help, advice, correction, and patience during research.
2. Mr. Agus Mansur, ST, M.Eng.Sc., and Mr. Muhammad Ridwan Andi Purnomo, ST, M.Sc., as examiner for their corrective advice.
3. Mr. Joko as my field supervisor, Mas Irlani, Mas Adi, Mas Ibnu and all staff of PT. Solo Grafika Utama and PT. Solopos for the cooperation and guidance.
4. My ancestor, for the mystical spirit that show your path of life I must continue.
5. My Parents and my little brother, your wish behind all of this.
6. To KH. Imaduddin Sukamto and Ustadz Zahid and big family of PP. Sunan Pandanaran for the best life moment.

7. International Program Management, especially Mrs. Diana.
8. My IP-classmates for the great competition we set up to push our limit.
9. My friends in PMII Yogyakarta Branch, especially in PMII UII. Thanks for the entire lesson I got in this secondary class.
10. Wisma Biru Family, that show me the taste of youth.
11. All the student of Industrial Engineering 06.
12. All persons and parties who has helped me to finish this report, which I can't mention one by one. Thank you so much.

The author realized that this report is still far away from perfection. So that, the author will accept any kind of critics and suggestion as a reference for a better research works. At last, hopefully this report be useful for anyone.

*Wassalamu 'alaikum Wr. Wb.*

Yogyakarta, December 2010.

Author

Khoirul Anwar

## ABSTRACT

*Facility layout is important factor to be considered because of its big and long term effect toward production cost incurred. This research analyzes performance of Attractors-Repeller approach for facility layout design. Attractors-Repeller approach is development of Non-Linear optimization Layout Technique which contributes to simplify phase one and two of Non-Linear optimization Layout Technique in single mathematical model. This simplification expected to provide better initial starting point for phase three so that it can be solved efficiently using suitable optimization algorithm. The objective of this research is to explore the behavior of Attractor Repeller approach for facility layout design and find the factor which determines that behavior. Case study in PT. Solo Grafika Utama gives a condition in where, from fifteen departments included, only seven departments that are able to move. In this case study, Attractors-Repeller approach succeeds to provide improvement only when overlap occurs. There is a trend in where material handling cost improvement leads to increase the number of overlap. Overlap occurs because assumption of target distance when value of  $\alpha$  reduced is smaller.*

*Keywords: facility layout, Attractor-Repeller, Non-Linear optimization Layout Technique.*



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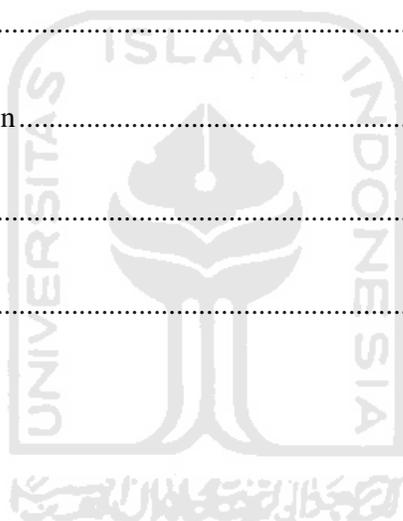
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# CHAPTER I

## INTRODUCTION

### 1.1 Background

The development of the industrial world requires companies to always maximize the available resources that are limited. Layout settings become important as one of the aspects that need to increase due to the layout settings have a big and direct impact on the smoothness of production process. A good layout supports the creation of the production process where a good product design, advanced equipment and good management fully utilized.

The main objective of the design layout is to minimize material handling costs. Transfer of material will require a fee known as material handling costs. The magnitude of these costs will range from 25% - 50% of production costs incurred (Tompkins and White 1984). Based on the study of manufacturing systems by Sule (1991) identifies 30% - 75% of production costs is the cost of material handling. In addition to smoothen the flow of material movement, a good layout can also provide a comfortable working environment for workers, thereby increasing their productivity. Both of these are possible because most of the factory layout is valid for a very long time.

Facility layout problem has been widely represented into mathematical models, and then optimized with suitable algorithm. Drezner (1980) introduced

DISCON (dispersion concentration) method, where each module of facilities approximated by circle and the distance was Euclidean distance between two center points of circles. DISCON use two phase approach, that are dispersion phase where all the circles are dispersed far from the origin, and concentration phase where they are brought as close together as possible. Recently, van Camp *et al.*, (1991) introduce NLT (Non-Linear optimization Layout Technique) which improve the DISCON method by adding ability to optimize the dimension of resulting facility. Non-Linear optimization Layout Technique use three phase method, first phase aims to evenly distribute the centres of the modules inside the facility, then in second phase reduce overlap between modules. Last stage is to determine the final solution.

This research analyze performance of Attractors-Repeller approach that is development of Non-Linear optimization Layout Technique. Attractor Repeller approach contribute to simplifize phase 1 and 2 of Non-Linear optimization Layout Technique in single mathematical model. This simplification will proposed better initial starting point for phase 3 so that it can be solved efficiently using suitable optimization algorithm.

## 1.2 Problem Formulation

Based on the facts in background problem stated above, some underlying problems are:

1. How is the performance of Attractors-Repeller approach for facility layout design?
2. Is Attractors-Repeller approach suitable for facility layout design?

3. What is determine suitability of Attractors-Repeller approach suitable for facility layout design

### **1.3 Problem Limitation**

Problem limitation aim to focus research interest so that purpose of research obtained in time and well controlled. To specify the interest of research, the problem boundary then defined as follows:

1. Research conducted at the production department with a focus on the production facility layout problem.
2. Calculation of production costs were conducted only on production costs in the production process.
3. The focus of the problems to be studied is limited to analyzing the layout of existing facilities.
4. It is assumed the number of machines and production equipment are sufficient, thus no analysis of the number of machines.
5. It is assumed that the width and shape of the remains unchanged.

### **1.4 Objective of Research**

1. Explore the behavior of Attractor Repeller approach for facility layout design.
2. Determine suitability of Attractor Repeller approach for facility layout design.
3. Find the factor that determine suitability of Attractor Repeller approach for facility layout design.

### 1.5 Research Significance

1. Keep production costs minimum.
2. Decreased production process time.
3. Production increased so as to produce big profits.
4. Can be used as an evaluation of company management regarding the layout of production facilities that applied by the company.

### 1.6 Writing Systematic

The outline of the writing of final report is as follows:

#### **CHAPTER I INTRODUCTION**

This chapter contains the background of the problem, formulation of the problem, the problem definition, research objectives, the benefits of systematic research and writing.

#### **CHAPTER II BASIC THEORY**

This chapter contains a brief description of the theories about the layout of the facility, objectives of facility layout, type of facility layout, models for facility layout problems, and some previous researches related to facility layout.

#### **CHAPTER III RESEARCH METHODOLOGY**

Research methodology contains the object of the research, methods of research, the data needed, and methods of data

collection, data processing methods, data analysis and problem-solving framework.

#### **CHAPTER IV DATA COLLECTING AND PROCESSING**

This chapter contains data collected from the research and data processing. The result of data processing appear either in the form of tables and figures. What is mean by data processing also includes the analysis conducted on the results obtained.

#### **CHAPTER V DISCUSSION AND ANALYSIS**

This chapter presents the analysis and interpretation of the results in previous chapter.

#### **CHAPTER VI CONCLUTION AND SUGGESTION**

This chapter is the last chapter of this thesis, which contains conclusions of the analysis and recommendations or suggestions from the results achieved and problems found during the study, so we need to review recommendations on further research.

#### **REFERNCES**

#### **APPENDIX**

## CHAPTER II

### LITERATURE REVIEW

#### 2.1 Facility Layout Problem

Facilities layout has become a very important issue in the industrial world. Because a very large influence on the smoothness of production process. A lot of research was done to find the best way to design facility layout. There exist many application of facility layout problem such as workshop organization, construction of new production units, or equipment assignment (Hani, *et al.*, 2006). Recent study by Wong and See (2008) tries to solve facility layout problem modeled by quadratic assignment problem using a hybrid ant colony optimization algorithm. Hybrid ant colony algorithm used is a combination between one of ant colony algorithm variant namely max-mint ant system and genetic algorithm. This hybrid algorithm was also improved using minimum pheromone threshold strategy. The result shown that the synergy effect between all components used in the hybrid algorithm causes the ant to search more aggressively, thus increasing its ability to obtain a better solution for quadratic assignment problem within a reasonable time. This research is the extension of similar research done by Hani, *et al.*, (2006) concern for solving industrial layout problem using ant colony optimization. Tate and Smith (1992) try a genetic approach to the quadratic assignment problem. In here, they found that genetic algorithm performed consistently equal or even better than previously known heuristics.

Some study used quadratic assignment problem approach to provide initial starting point before apply a meta-heuristic search on it (Wong and See, 2008; Tate and Smith, 1992). Quadratic assignment problem has been traditionally used to model facility layout problem with some assumption (Hani, *et. al.*, 2006). Quadratic assignment problem that was first introduced by Koopmans and Beckman (1957) is the problem of allocating a set of facilities to a set of locations to minimize the total cost associated not only with the distances between locations, but also with the flows. However, Bozer and Meller (1996) found that with a discrete representation, the quadratic assignment problem approach proposed in literature does not solve the distance based facility layout problem even if the quadratic assignment problem solved to optimality.

Another facility layout problem representation is DISCON (dispersion concentration) method found by Drezner (1980), where each components or modules within facility approximated by circle. DISCON methods works in two phases. The first phase is dispersion phase, in where all the circles dispersed far from the origin. This phase provide starting point for the next phase that are concentration phase. In concentration phase, the circles brought as close together as possible. The final arrangement from this phase is the final solution. Recent development of DISCON method by van Camp, *et al.*, (1991) provide ability to optimize the dimension of the resulting facilities. This developed method called NLT (Non-Linear optimization Layout Technique) method that consist of three phase which are at first phase, it evenly distribute the center of the modules inside facility. In stage two NLT method aims to reduce the overlap between modules and the last phase determine the final solution. Anjos and Vanelli (2001) try to improve the NLT method by Attractor-

Repellermodel. Attractor-Repellermodel replace stage one and two of NLT method by single mathematical model, which provide better initial starting point for solver at stage three.

## **2.2 Definition of Facility Layout**

Facility planning, especially in manufacturing industry conducted to optimize the physical assets in achieving corporate goals. In planning the facility, there are two main activities undertaken, namely planning the location of facility and designing the components of the facility. Facility components design consists of the structure design, layout planning, and design of handling systems (Meyers, 1993). For example in the planning of manufacturing facilities, the first activity is to plan where the location of the plant profitable. Next step is to design a new factory that consists of:

1. Structures Design: designing a factory building and its supporting systems such as power generation, water, gas, lighting, waste treatment systems, and so forth.
2. Layout Planning: set the configuration of the departments in the production area and office area.
3. Design of Handling Systems: designing material handling systems.

Facility layout defined as the planning and integration of components flow of a product to get the most effective interrelation and efficient among workers, equipment and material transformation process from the inception through the shipment of finished products (Apple, 1997). Layout Design is the design of location or configuration between departments, work stations, and equipment involved in the

process of converting raw materials into finished goods. From the definition described above, facility layout can be taken as configuration of departments or workstations and equipment that was formed based on the interaction between departments that meet certain criteria so that the interaction was optimal in the process of transforming raw materials into finished products in an effective, efficient, and safe way.

### **2.3 Objectives of Facility Layout Planning**

The main objective of designing the facility layout is to minimize costs that arise because of production activities consider other relevant aspects. These aspects are (Apple, 1997):

1. Related to the facility
  - a. Better Material handling plan in order to lower or eliminate material handling costs.
  - b. Shorten the processing time
  - c. Reduce idle time or delay time in machines utilization.
  - d. Reduce equipment investment
  - e. Flexible toward changes that is required in order to increase production or production changes.
2. Dealing with Labor.
  - a. Planning the use of human power effectively and efficiently.
  - b. Reducing the risk of accidents and maintain safety.
3. Dealing with materials and its flow.
  - a. Ensuring raw materials did not stay long in the factory.
  - b. Set a better way of material storage and flow in order to save space.

## **2.4 Types of Facility Layout**

Facility layout cannot be separated with the current production system. Basically, the operating system or production system is divided into two basic types (Apple, 1997), namely:

1. Continuous operation, which is characterized by high production volume, use of special equipment, less product variation, product standardization, and there are inventory products.
2. Non-continuous operation, characterized by low production volumes, the use of common equipment, production flow is not continuous, frequent schedule changes, high product variety and products made as to meet customer orders.

The operating systems defined above have consequences on the type of facility layout. Four basic facility layout types (Apple, 1997) are:

### **2.4.1 Process Layout**

Process-oriented layout is suitable for non-continuous operating system. This is due to the grouping of workstation based on functions performed. High products variety as high as variation of the production process causes the material flow is not standard for all units.

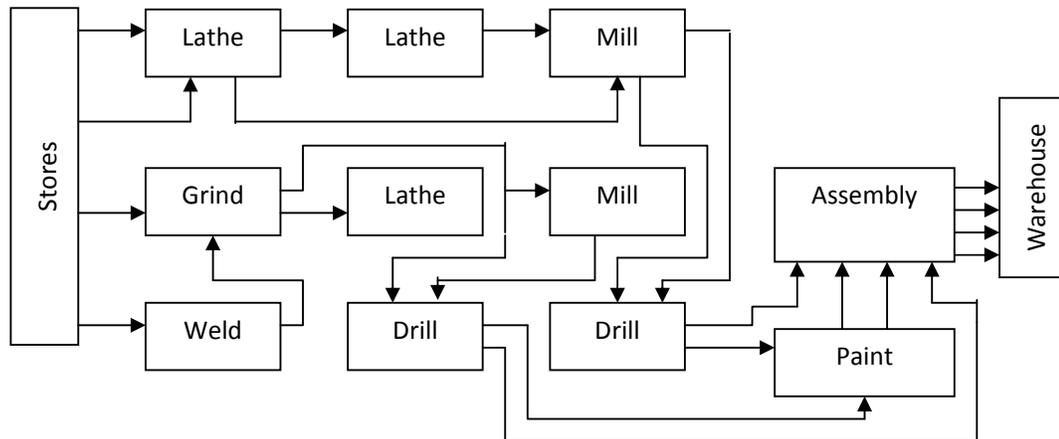


Figure 2.1. Process Layout

### 2.4.2 Product Layout

Product-oriented layout used when producing a standard product. Product layout usually applied to the continuous operating system. Each products unit require the same process sequence until the end, therefore the system was planned.

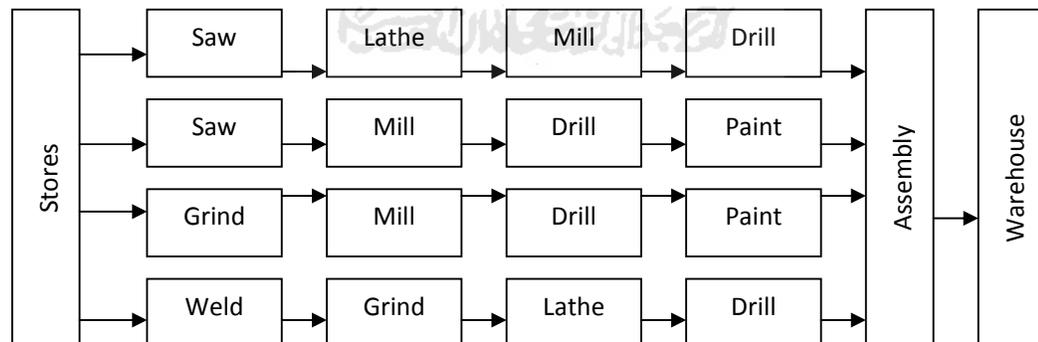


Figure 2.2. Product Layout

### 2.4.3 Fixed Position Layout

Unlike two previous layout types, fixed type layout applied to industries that manufacture products with size, shape and other characteristics that make it cannot be moved. Product placed in a fixed location, with equipment, tools, and operators undertake the transformation.

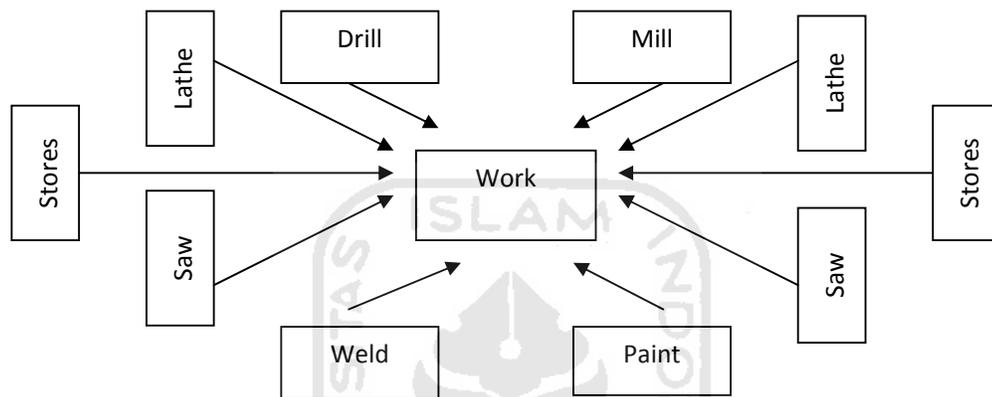


Figure 2.3. Fixed position layout

### 2.4.4 Group Technology Layout

Procedures of this type based on the grouping of products or components to be created. Products - products that are not identical grouped based on processing steps, forms, machinery or equipment used, and so forth. Here the classification not based on the similarity of the final product as the product type layout.

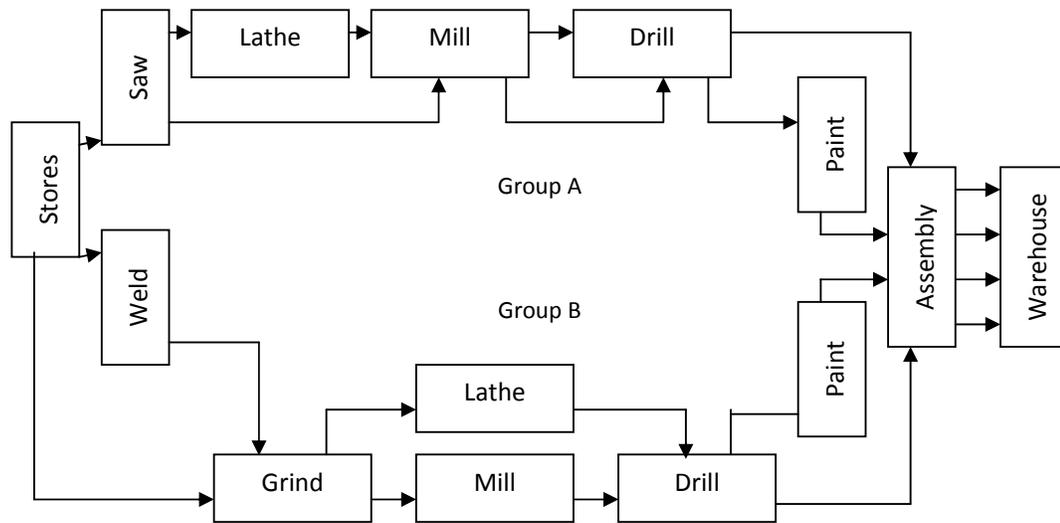


Figure 2.4. Group Technology Layout

## 2.5 Models for Facility Layout Problem

The facility layout problem is the one of the best-studied problems in field of combinatorial optimization since it's not just consider quantitative objective that is minimize material handling cost but also qualitative objectives such as safety, flexibility, and noise (Shouman *et al.*, 2001).

### 2.5.1 Quadratic Assignment Problem

Quadratic assignment problem is the first facility layout model that considers material flow. Its introduced by Koopmans and Beckman (1957) as quadratic assignment problem since the objective function is a second degree function of the variables and the constraints are linear function of the variables (Kusiak and Heragu, 1987). The Quadratic Assignment Problem formulation assigns every department to one location and at most one department to each location. The cost of placing a department at a

particular location is independent on the location of the interacting departments. Such dependencies lead to the quadratic objectives that inspire the problems name.

The Quadratic Assignment Problem has been frequently used to model the facility layout problem. However, this does not mean that all facility layout problems can be formulated as a Quadratic Assignment Problem. For example, consider the machine layout problem in which the locations of the machines are unknown initially. Such problems cannot be formulated as the Quadratic Assignment Problem because the distance between the locations cannot be determined. The distance  $d_j$  between locations  $j$  and  $i$  depends upon the sequence of arrangement of all the other machines.

### 2.5.2 Quadratic Set Covering Model

Bazaara (1975) formulated facility layout problem as a quadratic set-covering model. In this solution formulation, the total area occupied by all facilities is divided into a number of blocks where each facility is assigned to exactly one location and each block is occupied by at most one facility. The distance between location taken from centroid of the location and the flow between facilities is minimized. The disadvantages of this model is that the problem size increases as the total area occupied by all facilities is divided into smaller blocks (Shouman *et al.*, 2001).

### 2.5.3 Linear Integer Programming Model

Formulation of facility layout problem as a linear integer programming model was first introduced by Lawler (1963). He also proved that the model was equivalent to Quadratic Assignment Problem. Quadratic Assignment Problem has  $n^2k_{ij}$  variables and  $2n$  constraints while integer programming has  $n^4 + 2n + 1$  constraints and  $n^4y_{ijkl}$ ,

where  $n$  is the number of plans,  $X_{ij}$  is the integer variable of plant  $i$  at location  $j$ , and  $y_{ijkl}$  is the integer variable of plant  $i$  at location  $j$  in arrangement  $k$  of location  $l$  (Shouman *et al.*, 2001).

#### 2.5.4 Mixed Integer Programming Model

Kaufman and Broeckx (1978) develop a linear mixed integer programming model, which has the smallest number of variables and constraints among all integer programming formulation of the Quadratic Assignment Problem. This formulation has  $n^2$  (0-1) and  $n^2$  continuous variables and  $n^2 + 2n$  constraints (Shouman *et al.*, 2001).

#### 2.5.5 Graph-Theoretic Approach

A planar graph is such that it can be mapped onto a plane without any two of its edges intersecting (Kusiak and Heragu, 1987). In graph-theoretic formulations, it assumed that the desirability of locating each pair of facilities adjacent to each other is known (Foulds and Robinson, 1976). In this model, a closeness rating indicating desirability of locating facility  $i$  adjacent to facility  $j$  is assumed. The model seeks to minimize the closeness rating of the facilities (Shouman *et al.*, 2001).

#### 2.5.6 DISCON Method

DISCON (Dispersion Concentration) method which first introduced by Drezner (1980). To describe DISCON, first we denote modules  $1, \dots, N$ , where  $N$  is the total number of modules. Each modules are approximated by circle with  $r_i$ ,  $i = 1, \dots, N$ . This approximation following formula  $r_i = \frac{1}{2} \sqrt{\text{width} \times \text{height}}$ . The distance was Euclidean

distance between two center point of circle based on formula  $d_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$ . Complete formula of the DISCON methods is

$$\min_{(x_i, y_i)} \sum_{1 \leq i < j \leq N} c_{ij} D_{ij}$$

Subject to

$$d_{ij} \geq r_i + r_j, 1 \leq i < j \leq N$$

The constraints provided to ensure that there is no overlap between two circles.

### 2.5.7 Non-Linear Optimization Layout Technique

Recently, van Camp *et al.*, (1991) introduce NLT (Non-Linear optimization Layout Technique) method that develop DISCON method by adding ability to optimize the dimension of resulting facility. Using NLT method, user only has to specify the dimension of the resulting facility, and just let the model optimize the entire dimension within the facility.

$$\min_{(x_i, y_i)} \sum_{1 \leq i < j \leq N} c_{ij} D_{ij}$$

Subject to

$$d_{ij} \geq r_i + r_j, 1 \leq i < j \leq N$$

$$\frac{1}{2} w_T \geq x_i + r_i \text{ for } i = 1, \dots, N$$

$$\frac{1}{2} h_T \geq y_i + r_i \text{ for } i = 1, \dots, N$$

$$\frac{1}{2} w_T \geq r_i - x_i \text{ for } i = 1, \dots, N$$

$$\frac{1}{2} h_T \geq r_i - y_i \text{ for } i= 1, \dots, N$$

$$l_T^{\max} \geq \min (w_T, h_T) \geq l_T^{\min}$$

Where:

- $w_i, h_i$  are the width and height of module  $i$
- $l_i^{\min}, l_i^{\max}$  are the minimum and maximum allowable lengths for the shortest side of module  $i$
- $w_T, h_T$  are the width and height of the facility
- $l_T^{\min}, l_T^{\max}$  are the minimum and maximum allowable lengths for the shortest side of the facility.

The NLT method employs three stages to work, that are:

1. To evenly distribute the centers of the modules inside the facility;
2. To reduce the overlap between modules;
3. Determines the final solution.

### 2.5.8 Attractor Repeller Approach

More recent development of two previous methods done by Anjos and Vanelli (2001) by introducing Attractor Repeller approach. The contribution of Attractor Repeller approach is that this method tries to simplify stage one and stage two of NLT method by single mathematical model that find good initial point for solver at stage three. This approach employing target distance concept that are the optimum distance between two modules which are approximated by circle, so that the optimum distance equal radius of circle  $i$  and radius of circle  $j$  ( $r_1+r_2$ ) as shown in figure 2.1.

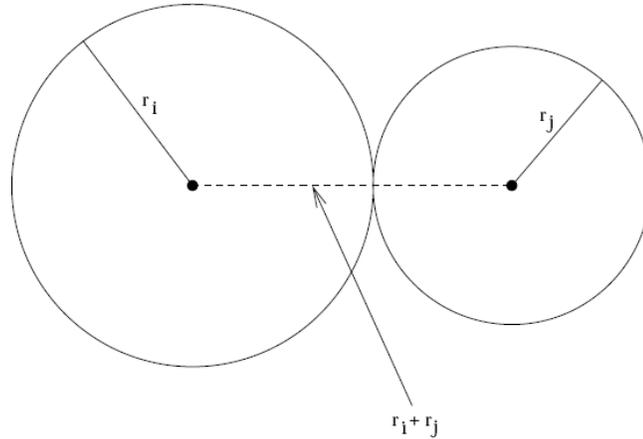


Figure 2.1. Optimum distance of two circles

For convenience reason, distance will be represented in square distance within Attractor Repeller approach so that  $D_{ij} = d_{ij}^2 = (x_i - x_j)^2 + (y_i - y_j)^2$ , and the target distances is  $t_{ij} = \alpha (r_i + r_j)^2$ , where  $1 \leq i < j \leq N$ .

Target distance enforced by used it as a penalty for the objective function by present it as a function  $f = \frac{D_{ij}}{t_{ij}}$  where the function defined by  $f(z) = \frac{1}{z} - 1$ ,  $z >$

0. Complete representation of Attractor Repeller approach is as follows:

$$\min_{(x,y), i \in M, hT, wT} \sum_{i,j \in M \cup P} c_{ij} D_{ij} + \sum_{i,j \in M} f\left(\frac{D_{ij}}{t_{ij}}\right)$$

Subject to

$$\frac{1}{2} w_T \geq x_i + r_i \text{ and } \frac{1}{2} w_T \geq r_i - x_i, \text{ for all } i \in M,$$

$$\frac{1}{2} w_T \geq y_i + r_i \text{ and } \frac{1}{2} w_T \geq r_i - y_i, \text{ for all } i \in M,$$

$$w_T^{\max} \geq w_T \geq w_T^{\min}$$

$$H_T^{\max} \geq H_T \geq H_T^{\min}$$

Initially, the value of the existing distance is greater than the target distance ( $D_{ij} > t_{ij}$ ), and so  $\frac{D_{ij}}{t_{ij}} > 1$ . As the ratio of  $\frac{D_{ij}}{t_{ij}}$  decrease as the effect of objective function that attracts the circles, the function  $f$  behaves as repeller that maintains the circle from overlapping. Those two functions will interact until they achieve equilibrium.



## CHAPTER III

### RESEARCH METHODOLOGY

#### 3.1 Object of Research

This research done in PT. Solo Grafika Utama located at Griya Solopos, Adisucipto Street, No. 190, Solo. PT. Solo Grafika Utama is a subsidiary of PT. Aksara Solopos. PT. Solo Grafika Utama provide printing services for newspapers, magazines, tabloids, and books.

#### 3.2 Model

Attractor-Repeller Approach assumes that each department is a circle or can be approximate by circle. As the consequences, the distance between departments defined as the distance between centre points of two circles. Optimal distance occurs when two department are in touch without overlap. Optimal distance between two consecutive department represent in Target Distance, that are radius of source department plus radius of destination department.

The term Attractor represent by the objective function that seek to find minimum distance between departments by attract each department as close as possible. To prevent overlap between department, Repeller is needed. The term Repeller represent by a penalty function employing Target Distance concept. Those penalty work when two departments start overlapping, or in other words when Target Distance violated.

### 3.2.1 Model Algorithm

Notations used for the algorithm are:

$r_i$  = radius of circle of converted department

$w$  = width of department

$h$  = height of department

$c_{ij}$  = cost per unit distance between department

$D_{ij}$  = square distance between department

$d_{ij}$  = distance between department

$x_i, y_i$  = center point of department in Euclidean plane

$T_{ij}$  = square target distance

$t_{ij}$  = target distance

$z_{ij}$  = penalty coefficient

$K$  = large number to accentuate the effect of penalty function.

$\alpha$  = Flexibility Parameter.

And the algorithm is:

Step 1: Define radius of circle of converted department.

$$r_i = \frac{1}{2} \sqrt{w \times h} \quad \dots (3.1)$$

Step 2: Define squared distance between department.

$$D_{ij} = d_{ij}^2 = (x_i - x_j)^2 + (y_i - y_j)^2 \quad \dots (3.2)$$

Step 3: Define squared target distance between departments.

$$T_{ij} = t_{ij}^2 = \alpha (r_1 + r_2)^2 \quad \dots (3.3)$$

Step 4: Define penalty coefficient.

$$z_{ij} = (D_{ij}/T_{ij}) \quad \dots (3.4)$$

Step 5: Compute Initial Grand Total.

$$\text{Initial Grand Total} = \sum c_{ij} D_{ij} + K \cdot \sum f(z_{ij}) \quad \dots (3.5)$$

Step 6: Minimize  $d_{ij}$  value using solver.

Step 7: Compute Result Grand Total

First step of the algorithm above is to convert the layout into circle approximated layout. Each department converted into circle which is if assume that the department is a square, then the circle is the inner circle of those square.

Second step is define the square distance between department. Square distance used in Attractor Repeller approach for convenience reason, so that in third step, square target distance also used.

Third step is to define square target distance. In Attractor-Repeller framework, the objective function is:

$$\min \sum c_{ij} D_{ij} \quad \dots (3.6)$$

This function act as an attractor, that is the function that seek to find smallest value of  $d_{ij}$  by attracting all pairs of circle  $i, j$  to each other. Smallest value of  $d_{ij}$  occurs when

all centers of circle are in one same point. To prevent this condition, the target distance concept was introduced, that are the optimum distance between two modules.

The optimal distance or the target distance is:

$$t_{ij} = r_i + r_j \quad \dots (3.7)$$

with:  $t_{ij}$  = target distance

$r_i$  = radius of source department

$r_j$  = radius of destination department

since attractor repeller require to use square target distance, the formula is then

$$T_{ij} = \alpha (r_i + r_j)^2, \text{ where } \alpha > 0 \quad \dots(3.8)$$

Parameter  $\alpha > 0$  is introduced to provide some flexibility as to how tightly the model should enforce the target distance.

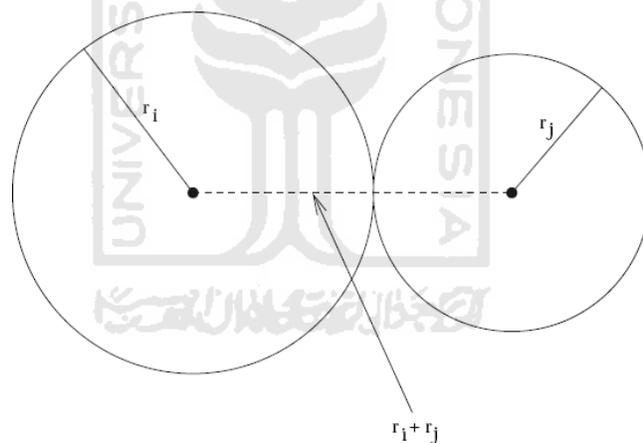


Figure 3.1. Target Distance

Fourth step is to define the penalty coefficient, that is the implementation of the target distance concept. Target distance employed as a penalty for the objective function by treat it as a function  $f(D_{ij}/T_{ij})$  in where  $f(z) = (1/z) - 1$ . Initially,  $D_{ij} > T_{ij}$  so that  $(D_{ij}/T_{ij}) > 1$  and  $f(z) < 0$ . Ideally, when target distance reached,  $D_{ij} = T_{ij}$  therefore  $(D_{ij}/T_{ij}) = 1$  and  $f(z) = 0$ . The use of function  $f(z) = (1/z) - 1$  as a penalty is to stop the objective function when  $f(z)$  come larger than zero which means that  $D_{ij} < T_{ij}$  or when

two circle start overlapping. To strengthen the effect of  $f(z) = (1/z) - 1$  toward the objective function, it used large number of  $K$  as the penalty to make sure that so that  $K$  dominates all cost coefficients. Suggested value of  $K$  is

$$K = 10.(\sum c_{ij}) \quad \dots (3.10)$$

Fifth step is finalization of the model before optimize it. After the model is complete, it means that current condition or performance of initial layout represented in the model. The complete model is then

$$\min \sum c_{ij}D_{ij} + K. \sum f(z_{ij}) \quad \dots (3.11)$$

subject to:

$$\frac{1}{2} w_T \geq x_i + r_i \text{ and } \frac{1}{2} w_T \geq r_i - x_i, \text{ for all } i \in M,$$

$$\frac{1}{2} w_T \geq y_i + r_i \text{ and } \frac{1}{2} w_T \geq r_i - y_i, \text{ for all } i \in M,$$

$$w_T^{\max} \geq w_T \geq w_T^{\min}$$

$$H_T^{\max} \geq H_T \geq H_T^{\min}$$

where:

$$D_{ij} = d_{ij}^2 = (x_i - x_j)^2 + (y_i - y_j)^2$$

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

$$f(z) = \frac{1}{z} - 1 \text{ for } z > 0$$

$$t_{ij} = \alpha (r_i + r_j)^2, \forall 1 \leq i < j \leq N$$

with:

$$(x_i, y_i) = \text{the centre of the } i^{\text{th}} \text{ department}$$

$r_i$  = the radii of the  $i^{\text{th}}$  department

$c_{ij}$  = cost per unit distance between department  $i$  and  $j$

$d_{ij}$  = distance between department  $i$  and  $j$

$t_{ij}$  = target distance between department  $i$  and  $j$

$w_i$  = width of the  $i^{\text{th}}$  department

$h_i$  = height of the  $i^{\text{th}}$  department

$w_F$  = width of the facility

$h_F$  = height of the facility

$w_F^{\text{max}} / w_F^{\text{min}}$  = maximum/ minimum allowable width of facility

$h_F^{\text{max}} / h_F^{\text{min}}$  = maximum/ minimum allowable height of facility

Sixth step is to minimize the model using excel solver that uses the Generalized Reduced Gradient (GRG2) nonlinear optimization code. This algorithm will seek to find best position of department that will minimize the material handling cost. Last step is the result of those optimization.

### 3.3 Required Data

Data required to do the experiment is based on the requirement of the model. The data divide into two categories that are General data and Special data. General data is data that required to understand the problem. Special data is data that directly used within calculation in the model.

#### 3.3.1 General Data

General data provide information about company in general manner, including:

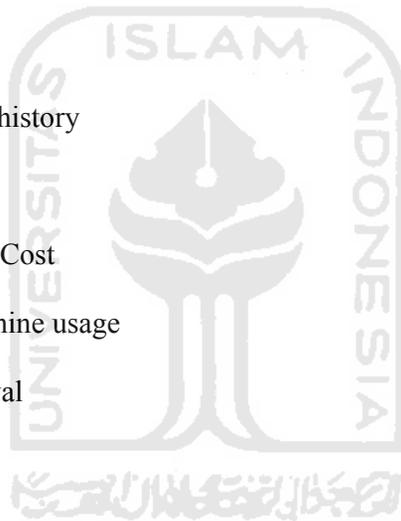
1. Company's Product

2. Tools
3. Materials
4. Work hours

### **3.3.2 Special Data**

Special data provide data that closely related to the research and are required to solve the problems, including:

1. Production process
2. Production history
3. Material expenses history
4. Machine capacity
5. Material Handling Cost
6. Percentage of machine usage
7. Shipment and arrival
8. Inventory level
9. Percentage of leftover paper
10. Existing layout



## **3.4 Data Collecting Methods**

### **3.4.1 Literature Review**

Collection method is done by reviewing some references, scientific reports and scientific papers that can support the formation of the model.

### 3.4.2 Field Research

To get accurate and precise data, the methods performed are:

1. The interview method, which is done by asking direct questions either orally or in writing to the relevant parties.
2. The method of documentation, namely by looking at past data from company reports and accounting records.
3. Direct measurement method, meant to measure some parameters directly within research.

### 3.5 Tools

Facility layout is a complex computational problem with several variables and constraints that need a special tool to solve. Spreadsheet provides ability to solve such problem. Instead of its commonality, spreadsheet actually has very big potential that are undiscoverable by users. Spreadsheet application used in this research is Microsoft Office Excel 2007. The problem will be modelled within Microsoft Office Excel 2007 and will be optimized by using built in Solver.

The Microsoft Office Excel Solver tool uses the Generalized Reduced Gradient (GRG2) nonlinear optimization code. Since the problem is nonlinear, The Microsoft Office Excel Solver is appropriate to use. The GRG2 code has been proven in use over many years as one of the most robust and reliable approaches to solving difficult nonlinear optimization problems.

### 3.6 Analysis Method

The results from the Attractor Repeller model that already maximized is then compared with Initial Layout using total material handling cost as the parameter. From that, we can find if there was an improvement or not, and also rate of the improvement. The material handling cost formula is as follows:

$$C_{ij} = c_{ij} \times f_{ij} \times d_{ij} \quad \dots (3.12)$$

With:

$c_{ij}$  = material transfer cost from department  $i$  to department  $j$ .

$f_{ij}$  = material transfer frequency occur between department  $i$  to department  $j$ .

$d_{ij}$  = distance between department  $i$  to department  $j$ .

Total material handling cost formula then:

$$\sum C_{ij} = \sum (c_{ij} \times f_{ij} \times d_{ij}) \quad \dots (3.13)$$

Five experiment varying value of  $\alpha$  conducted and corresponding improvement compared with overlap analyzed.

### 3.7 Problem Solving Framework

A study can be said to be correct if the steps to be taken can be categorized appropriately. This because the steps are correlated each other. So as to facilitate understanding of the problems that occurred, then a framework to solve the problem created. Flow chart that contains the framework of solving the problem shown in the Figure 3.2.

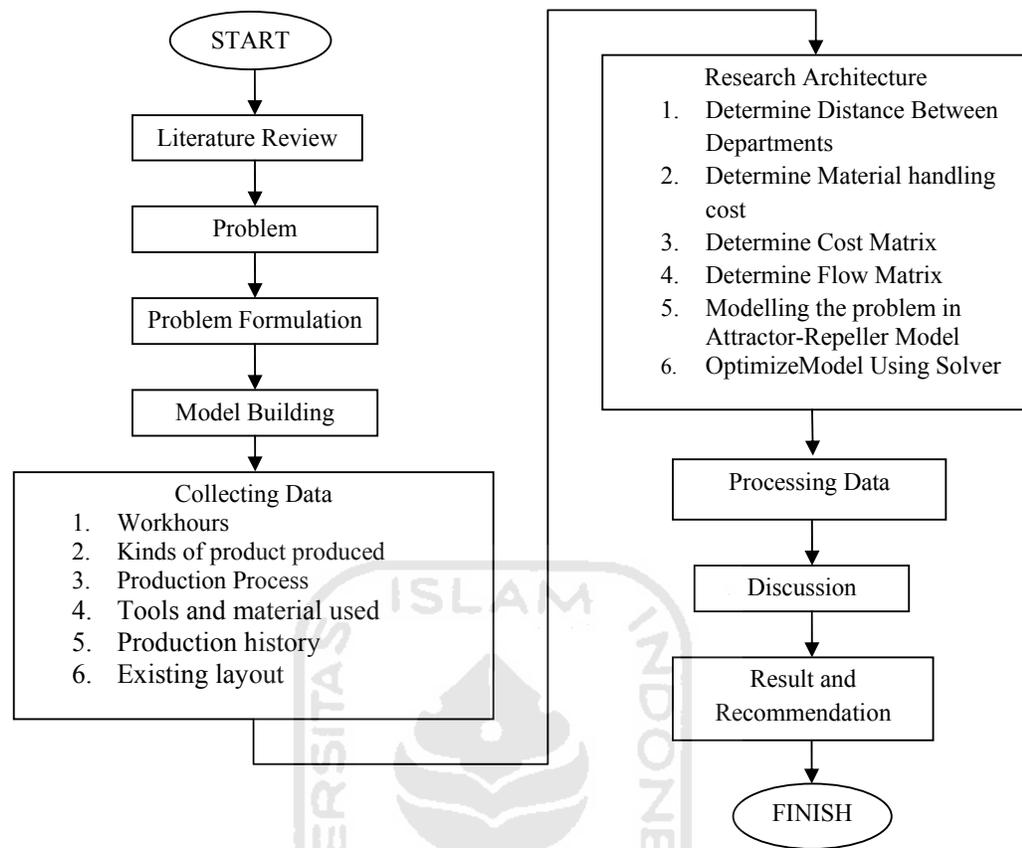


Figure 3.2. Problem Solving Framework

## **CHAPTER IV**

### **DATA COLLECTING AND PROCESSING**

#### **4.1 Company Products**

PT Solo GrafikaUtama produces various types of printed products. In general, the products of PT Solo Grafika Utama can be categorize in two types that are newspaper and books. Some newspapers printed are Solopos, Soloraya, Media Indonesia for Central Java distribution and Harian Jogja. PT Solo GrafikaUtama also print for Al- Qur'an and some kind of educational books that are Students Worksheets, a study supplement for junior and senior high school and kindergarten magazines.

#### **4.2 Machines and Equipments**

In their production process, PT Solo GrafikaUtama require some machines and equipment, that are:

1. Image Setter: this machine print document softcopy into film. Film is a transparent medium useful for illumination process in the next step.
2. Plate Maker: this machine plots the image from film into plate incorporating illumination of chemical particle that covering raw plate. Through this illumination process, the chemical particle covering the raw plate faded following pattern of the film.

3. Offset printing Machine: contain some rolling folder in which plate resulted from previous process folded. Plate function as a stamp that transfer inks to paper surface. Since the machine is long enough, we divide the machine into three subdepartment that are:
  - a. Machine input
  - b. Machine body
  - c. Machine output

Based on material flow, each subdepartment correlated with another different department. Machine input subdepartment for example, is correlated with paper warehouse, but machine output is not. This division is necessary to increase calculation accuracy. PT Solo Grafika Utama has two machines, the old and new one. Note that in the old machine, the machine input and the machine body is not in parallel but in pile up configuration. This situation makes machine input and machine body of the old machine consider as one department.

4. Forklift: kind of forklift used in PT Solo Grafika Utama used only to transfer folded paper, so that it has a special grip that fit with the shape and size of the folded paper.
5. Handlift: tool used to carry finished printings which are usually stacked in a pad called palette. It needs 3 or 4 people to operate handlift in full palette capacity.
6. Palette: is a pad and horseblock for finished printing. It also function as buffer to temporary store finished product near the machine output before transported to final storage. A palette able to store up to 400 exemplar of finished printings.

### 4.3 Materials

Raw materials used in production process in PT. Solo Grafika Utama are:

1. Paper: paper used for offset printing was folded in a roll with  $\pm 1$  meter diameter. The roll width varies from 0.63, 0.72, and 0.80 meter. The average weights of one roll of paper usually around 500 kg. There are two kinds of paper used that are CD paper and HVS paper. CD paper is the default paper for newspaper and HVS usually used for books.
2. Ink: there are two kinds of ink used, black and color ink. Color inks consist of three basic colors that are cyan, magenta, and yellow. It is because printing industries used CMYK color format for their process.

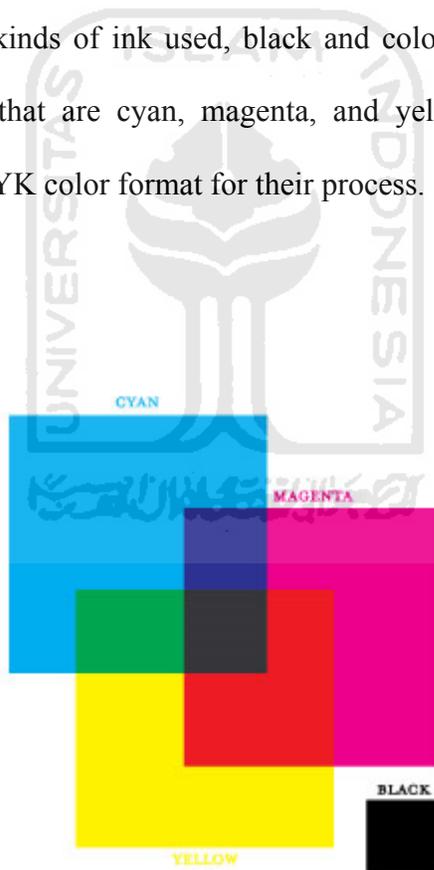


Figure 4.1 CMYK Color Process

3. Plate: Plate used to transfer ink from the ink pool into paper surface based on the pattern printed therein.

#### **4.4 Work Hours**

The working hours arrangements in PT Solo Grafika Utama is divided into two, which are dayshift from 08.00 AM until 04.00 PM with one hour rest time and nightshift start from 09.00 PM until 04.00 AM with no rest time. Total workhours for a day is then 14 hours.

#### **4.5 Data Collecting**

##### **4.5.1 Production Process**

Production process that is run by the company through several stages, which are:

1. Film making, a process of printing the newspaper softcopy material (generally portable digital format or PDF) into a transparent medium called film. In this process, CMYK color separation is already take place, so that for a color pages require four sheet of film.
2. Montage, came from French word means joining or put together. Early definition of montage in newspaper industries is joining column of writings and images. But because of today's graphical computer technology, montage is done through software before film making. However, in book production, since the size-format used is web, there will be more than two pages of book in every page of the

printing and so for the film and plate. This require proper placement configuration of book pages within the film. This is what montage uses today. Montage function to properly place book pages so that it will make ease when cut the printings into book size.

3. After the film is ready, it brings to plate maker machine to be used as a pattern for plate illumination. This illumination process lets the photochemical material covering the plate fade except which are under printed text and image.
4. Printing process begin with attached plate into plate cylinder within printing machine. The work principle is that the rest of photochemical material absorb ink and transferred it to the paper facilitate by offset cylinder. Offset cylinder function to mirror the image and preserve direct friction between plate and the paper. In a high speed machine run, friction between plate and the paper can grind the photochemical material.

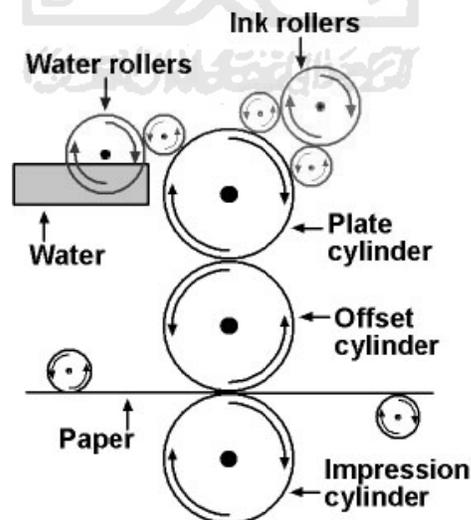


Figure 4.2 Printing Process

5. Quality control. Newspaper comes out from printing machine in batch of fifty exemplars. Most of the defect occurs is color misalignment, beside another type of defect such broken paper and less color intensity. Misalignment occurs at early run of the machine. The plate attached in plate cylinder got a little shock resulted from machine vibration, so that it need to set up plate placement while the machine run in low speed.

The process is summarized in the flowchart and operation process chart below:



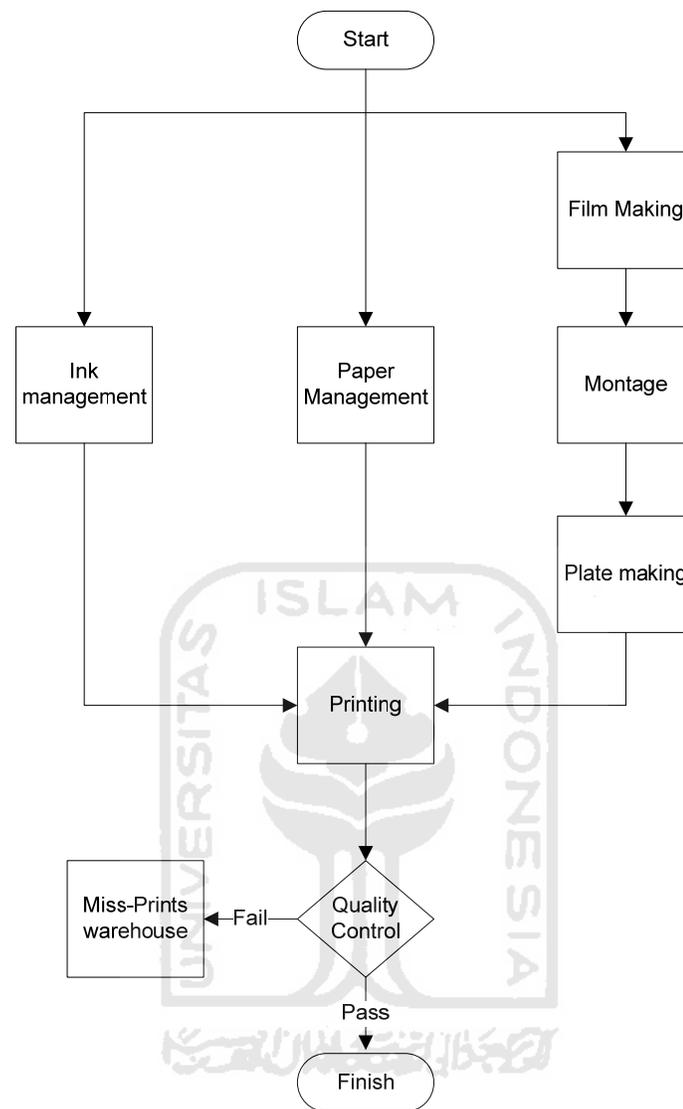


Figure 4.3 Process Flow Chart

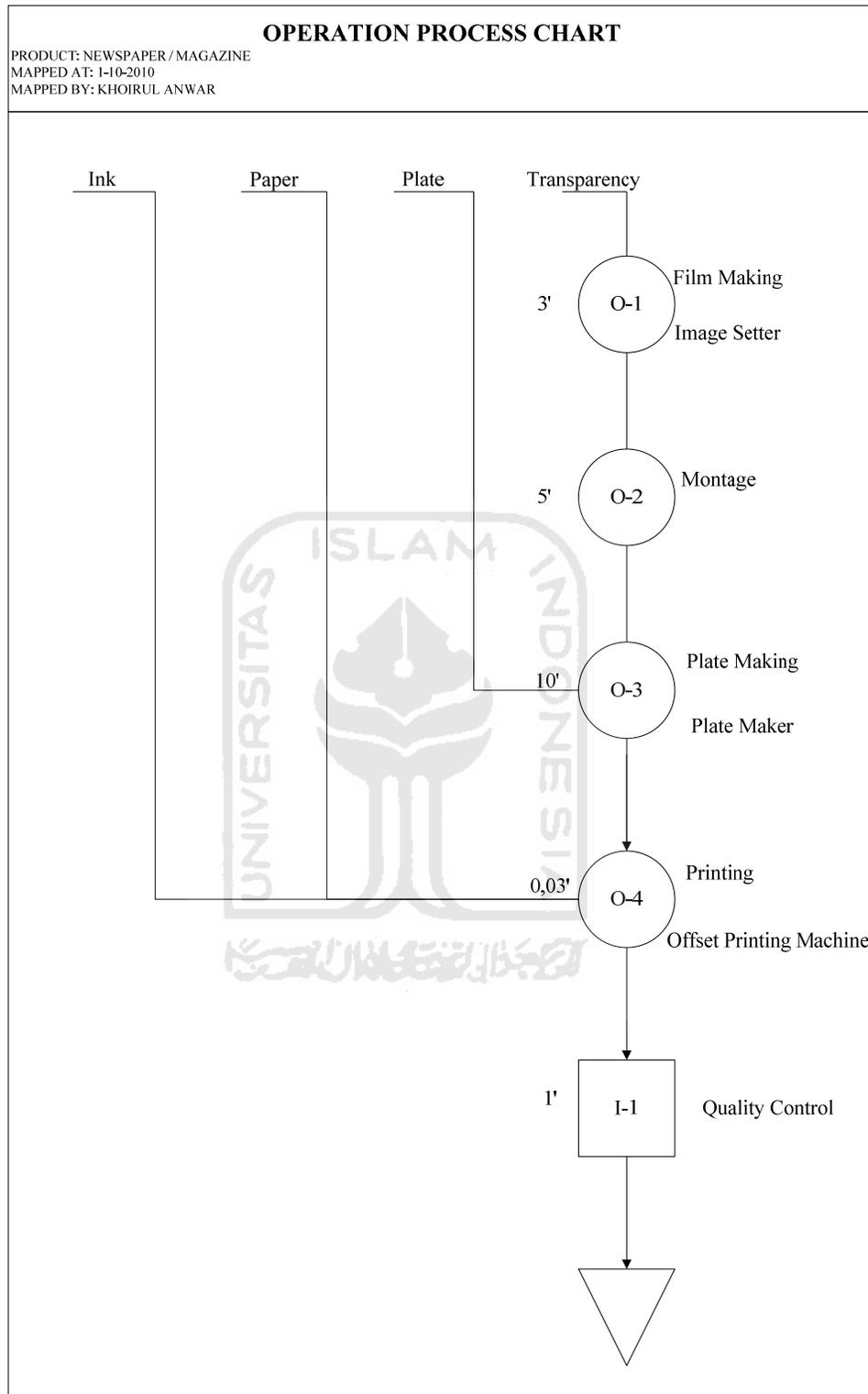


Figure 4.4 Operation Process Chart

#### 4.5.2 Production History

From the experiment that starts at June 2010, we collect the data of production for one year interval. Record from the company show the monthly average production for newspapers and books summarized in Table 4.1. Measurement unit used here is the company standards that are exemplars.

Table 4.1 Production History

No	Month	Products	
		Newspaper (exemplars)	Books (exemplars)
1	January 2010	1500000	1200000
2	February 2010	1500000	500000
3	March 2010	1500000	300000
4	April 2010	1500000	1200000
5	Mey 2010	1500000	1500000
6	June 2010	1500000	1200000
7	July 2009	1500000	500000
8	August 2009	1500000	300000
9	September 2009	1500000	500000
10	October 2009	1500000	1500000
11	November 2009	1500000	1200000
12	December 2009	1500000	1000000

### 4.5.3 Material Expenses History

Material expenses is calculation of raw materials used by the company to produce the product. The average monthly materials expenses for one year time interval summarized in Table 4.2.

Table 4.2 Material Expenses History

No	Month	Materials			
		Plate (sheet)	Ink (bucket)	CD paper (roll)	HVS paper (roll)
1	January 2010	3150	126	240	192
2	February 2010	2334	94	240	80
3	March 2010	2100	84	240	48
4	April 2010	3150	126	240	192
5	Mey2010	3500	140	240	240
6	June 2010	3150	126	240	192
7	July 2009	2334	94	240	80
9	September 2009	2334	94	240	80
10	October 2009	3500	140	240	240

No	Month	Materials			
		Plate (sheet)	Ink (bucket)	CD paper (roll)	HVS paper (roll)
11	November 2009	3150	126	240	192
12	December 2009	2917	117	240	160

#### 4.5.4 Machine Capacity

PT. Solo Grafika Utama has two machines with different capacity, either for output or for the defect rate. That capacity was summarized in the table below.

Table 4.3 Machine Capacity

No	Machine	Output (Exemplar/hours)	Defect rate
1	New	30000	3.00%
2	Old	17000	5.00%

#### 4.5.5 Material Handling Cost

Company used three kinds of conveyance within their production process, that are handlift, forklift, and human conveyance. Management from PT. Solo Grafika Utama decide the material handling cost for three types of conveyance used as follows:

Table 4.4 Material Handling Cost

No	Conveyance	Cost (Rp/m)
1	Human	5
2	Handlift	20
3	Forklift	30

#### 4.5.6 Percentage of Machine Usage

Since there are two machine with different capacity and capability, the job allocation is not equal. Inequality of job allocation also caused by the down of the old machine that frequently occurs. Here the summary of the percentage of machine usage in Table 4.5.

Table 4.5 Percentage of Machine Usage

No	Product	Machine	Usage
1	Newspaper	New	70 %
		Old	30 %
2	Books	New	50 %
		Old	50 %

#### 4.5.7 Shipment and Arrival

Since PT. Solo Grafika Utama provide only services, the matter of shipment is not in their concern. PT. Solo Grafika Utama only store all finished goods and it will be picked up by clients. Newspaper for example, clients picked up their order every day but for book and another product that are not daily distributed, clients picked up when the order is finished. Table 4.6 below are the summarizes of monthly shipments occurs during one year time interval.

Table 4.6 Shipment History

No	Month	Shipment (times)
1	January 2010	24
2	February 2010	10
3	March 2010	6
4	April 2010	24
5	Mei 2010	30
6	June 2010	24
7	July 2009	10
8	August 2009	6
9	September 2009	10

No	Month	Shipment (times)
10	October 2009	30
11	November 2009	24
12	December 2009	20

For arrival, there are two arrivals for paper in one month. Another material such as ink, film, plate, and another supporting material is purchased once in a month.

#### 4.5.8 Inventory Level

Company management policy decided to keep material safety stock of paper by 20% each, both for CD and HVS paper.

#### 4.5.9 Percentage of Leftover Paper

Leftover paper is that a roll of paper that are not entirely used. The remaining paper will be used for another printing only if the remaining roll diameter is more than 10 cm. Based on historical data of the company, there are 25% of leftover papers.

#### 4.5.10 Initial Layout

The initial layout of PT Solo Grafika Utama production floor is in Figure 4.5. below, with length equal 34 meter and height equal 38 meter.

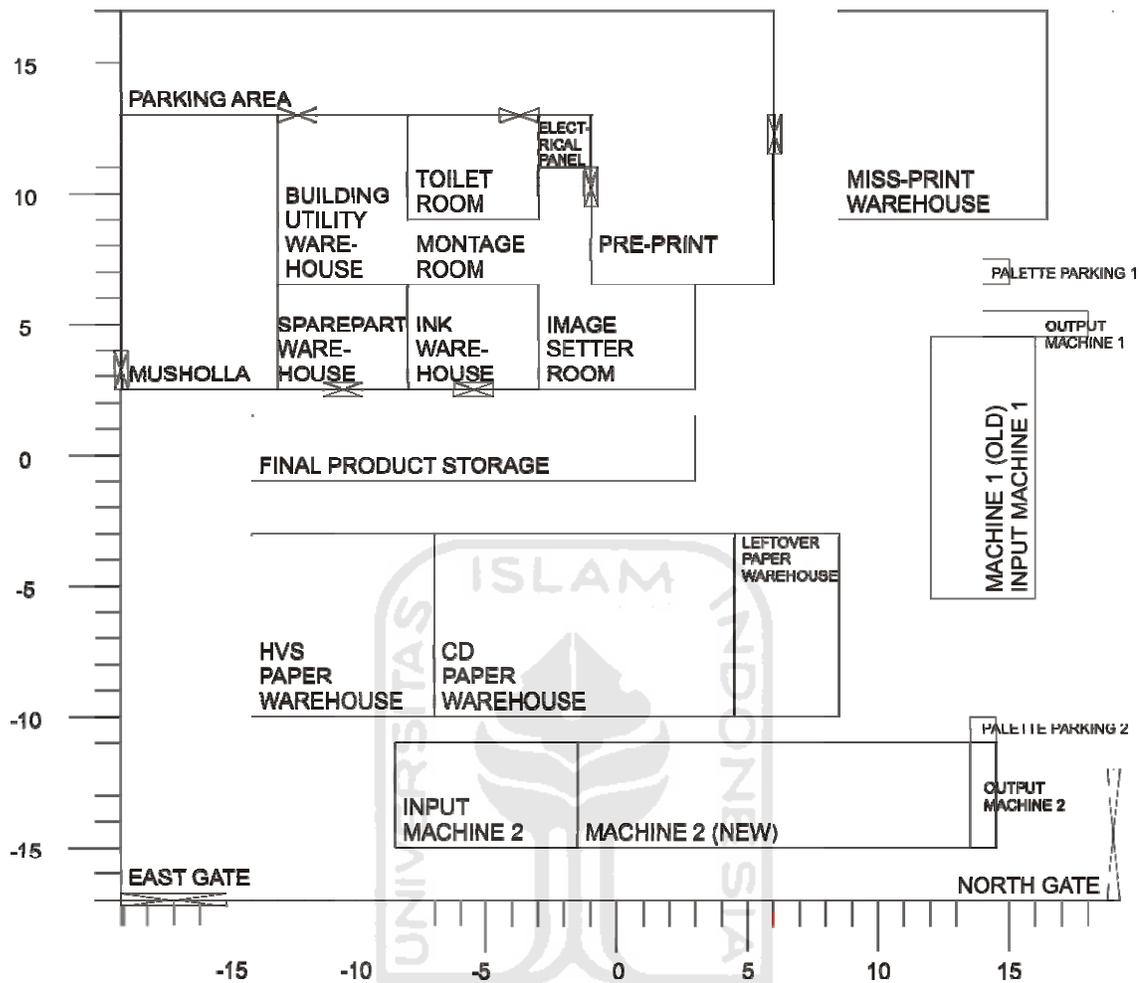


Figure 4.5 Initial Layout of the Facility

Based on the context of the problem that is to improve transportation efficiency in initial layout, not all the departments are re-arranged. Department that are unable to moved because of its construction already fixed so that re-arrangement consider expensive categorize as static department. Some static departments are not considered within calculation because they are not transferring any material, or assumed not doing so. Departments that are considered within calculation with its corresponding centroids summarized in the Table 4.7 below:

Table 4.7. Department Centroid

Department name	Centroid	
	x-axis	y-axis
Ink warehouse	-5.5	4.5
CD paper warehouse	-1.25	-6.5
HVS paper warehouse	-10.5	-6.5
Leftover paper warehouse	6.5	-6
Pre-print	2.5	9.75
Old Machine/input Old Machine	14	-0.5
New Machine	6	-13
Input New Machine	-5	-13
Output Old Machine	16	5
Output New Machine	14	-13
Palette parking 1	14.5	7
Palette parking 2	14	-10.5
Missprint warehouse	12.5	13
Product storage	-5.5	0.25
North gate	18.645	-14.5
East gate	-17	-16.7

From all departments that listed in Table 4.7, departments that possible to move (dynamic departments) are:

- a. Product storage.
- b. Missprint warehouse.
- c. Palette parking.
- d. CD Paper warehouse.
- e. HVS Paper warehouse.
- f. Leftover paper warehouse.

#### 4.6 Data Processing

Attractor-Repeller Approach assumes that each department is a circle or can be approximated by circle. The conversion of each department into circle according formula 3.1. For example, the conversion of Ink warehouse department is as follows:

$$\begin{aligned}
 r_{\text{Ink warehouse}} &= \frac{1}{2} \sqrt{w \times h} \\
 &= \frac{1}{2} \sqrt{4 \times 5} \\
 &= 2,23
 \end{aligned}$$

The result of conversion is in circle approximated layout below:

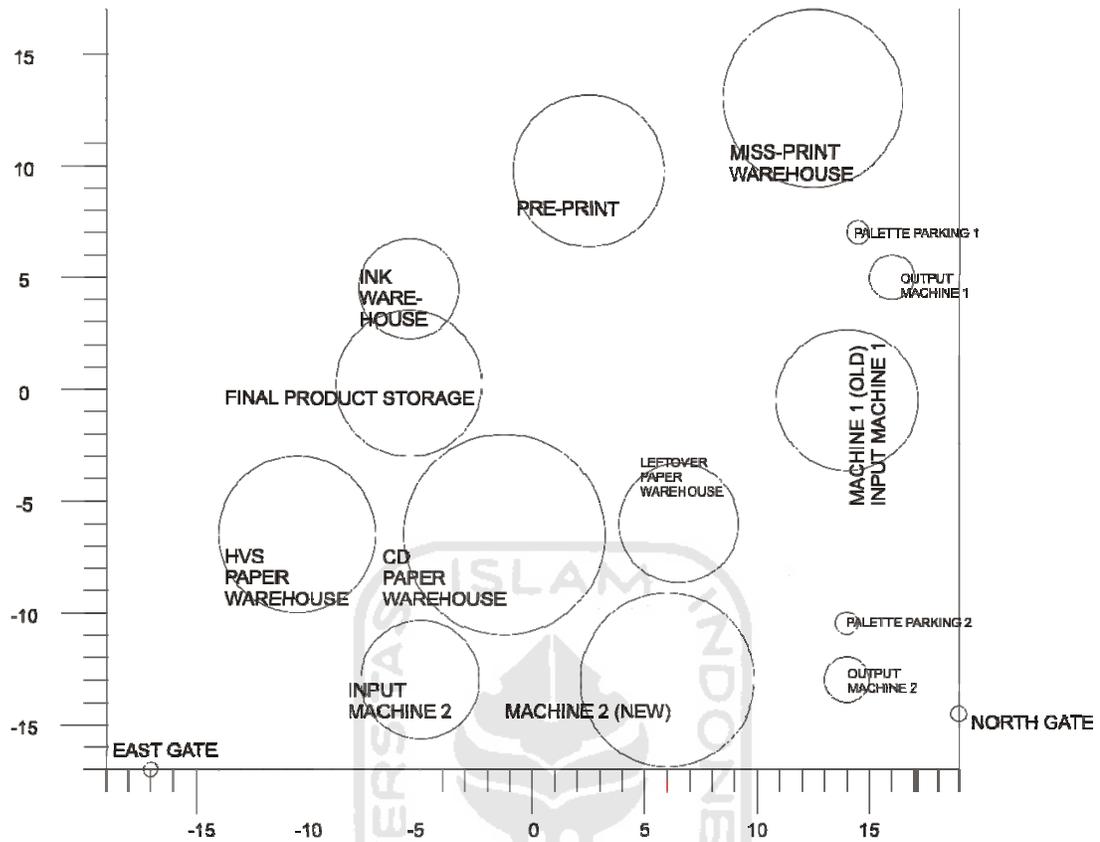


Figure 4.6 Circle Approximated Layout of the Initial Facility

#### 4.6.1 Euclidean Distance between Departments

Determination of distance between departments in the initial facility layout used by the company based on Euclidean distance calculation by the formula 3.2. for example:

$$\begin{aligned}
 d_{\text{Ink warehouse, CD paper warehouse}} &= \sqrt{(-5 - (-10))^2 + (5 - (-10))^2} \\
 &= \sqrt{25 + 225} \\
 &= 11,79
 \end{aligned}$$

Distance between departments summarize in distance matrix in Table 4.8 below

Table 4.8 Distance Matrix

Dept	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A	0.00	11.79	12.08	15.95	9.57	20.13	20.94	17.51	21.51	26.20	20.16	24.60	19.91	4.25	30.72	24.11
B	11.79	0.00	9.25	7.77	16.68	16.39	9.74	7.50	20.73	16.58	20.74	15.77	23.86	7.98	21.44	18.76
C	12.08	9.25	0.00	17.01	20.81	25.22	17.73	8.51	28.89	25.35	28.41	24.82	30.15	8.40	30.22	12.08
D	15.95	7.77	17.01	0.00	16.25	9.30	7.02	13.46	14.53	10.26	15.26	8.75	19.92	13.53	14.82	25.82
E	9.57	16.68	20.81	16.25	0.00	15.40	23.02	23.95	14.31	25.49	12.31	23.29	10.51	12.42	29.13	32.85
F	20.13	16.39	25.22	9.30	15.40	0.00	14.84	22.74	5.85	12.50	7.52	10.00	13.58	19.51	14.75	34.97
G	20.94	9.74	17.73	7.02	23.02	14.84	0.00	11.00	20.59	8.00	21.73	8.38	26.80	17.54	12.73	23.29
H	17.51	7.50	8.51	13.46	23.95	22.74	11.00	0.00	27.66	19.00	27.93	19.16	31.34	13.26	23.69	12.55
I	21.51	20.73	28.89	14.53	14.31	5.85	20.59	27.66	0.00	18.11	2.50	15.63	8.73	22.02	19.68	39.49
J	26.20	16.58	25.35	10.26	25.49	12.50	8.00	19.00	18.11	0.00	20.01	2.50	26.04	23.58	4.88	31.22
K	20.16	20.74	28.41	15.26	12.31	7.52	21.73	27.93	2.50	20.01	0.00	17.51	6.32	21.11	21.90	39.41
L	24.60	15.77	24.82	8.75	23.29	10.00	8.38	19.16	15.63	2.50	17.51	0.00	23.55	22.27	6.13	31.61
M	19.91	23.86	30.15	19.92	10.51	13.58	26.80	31.34	8.73	26.04	6.32	23.55	0.00	22.06	28.18	41.85
N	4.25	7.98	8.40	13.53	12.42	19.51	17.54	13.26	22.02	23.58	21.11	22.27	22.06	0.00	28.29	20.47
O	30.72	21.44	30.22	14.82	29.13	14.75	12.73	23.69	19.68	4.88	21.90	6.13	28.18	28.29	0.00	35.71
P	24.11	18.76	12.08	25.82	32.85	34.97	23.29	12.55	39.49	31.22	39.41	31.61	41.85	20.47	35.71	0.00

## TABLE INFORMATION:

1. Department A = Ink warehouse
2. Department B = CD paper warehouse
3. Department C = HVS paper warehouse
4. Department D = Leftover paper warehouse
5. Department E = Pre-print
6. Department F = Old Machine/input Old Machine
7. Department G = New Machine
8. Department H = Input New Machine
9. Department I = Output Old Machine
10. Department J = Output New Machine
11. Department K = Palette parking 1
12. Department L = Palette parking 2
13. Department M = Missprint warehouse
14. Department N = Product storage
15. Department O = North gate
16. Department P = East gate

#### 4.6.2 Material Transfer Frequency

Material transfer frequency describe how often material transfer between two consecutive departments occurs. Magnitude of material transfer frequency has different context for

every pair of consecutive departments. The frequency also influenced by many factors that are:

- a. Production level
- b. Material flow
- c. Lot size and batch size
- d. Material usage
- e. Machine usage
- f. Machine capacity

For example plate transfer from Pre-print to New Machine, the frequency will be:

$$\begin{aligned}
 F_{\text{Pre-print to New Machine}} &= \text{average monthly plate usage} \times \text{percentage of new machine usage} \\
 &= 2810 \times (70\% + 50\%) \\
 &= 1686.
 \end{aligned}$$

Same calculation will not appropriate for another transfer, so that there must be a single formula for a single transfer. The material transfer frequency and its corresponding formula summarize in Table 4.9 below

Table 4.9 Material Transfer Frequency

From	To	Material	Frequency formula	Frequency
Pre-Print	New Machine	plate	monthly plate usage X percentage of New Machine usage	1686
	Old Machine	plate	monthly plate usage X percentage of Old Machine usage	1124
Ink warehouse	New Machine	ink	monthly ink usage X percentage of New Machine usage	68
	Old Machine	ink	monthly ink usage X percentage of Old Machine usage	46
CD Paper Warehouse	Input New Machine	paper	monthly CD paper usage X percentage of New Machine usage for newspaper production	168
	Input Old Machine	paper	monthly CD paper usage X percentage of Old Machine usage for newspaper production	72
HVS Paper Warehouse	Input New Machine	paper	monthly HVS paper usage X percentage of New Machine usage for book production	73
	Input Old Machine	paper	monthly HVS paper usage X percentage of Old Machine usage for book production	73

<b>From</b>	<b>To</b>	<b>Material</b>	<b>Frequency formula</b>	<b>Frequency</b>
Leftover-paper warehouse	Input New Machine	leftover paper	percentage of leftover paper X monthly paper requirement X percentage of New Machine usage	58
	Input Old Machine	leftover paper	percentage of leftover paper X monthly paper requirement X percentage of Old Machine usage	39
Output New Machine	Palette Parking 2	product (books)	monthly book production X percentage usage of New Machine for books / batch size	9084
	Missprint Warehouse	missprint	monthly production X percentage of New Machine usage X missprint percentage	868
	North Gate	product (newspaper)	monthly newspaper production X percentage usage of New Machine for newspaper / batch size	21000
Output Old Machine	Palette Parking 1	product (books)	monthly book production X percentage usage of Old Machine for books / batch size	9084
	Missprint Warehouse	missprint	monthly production X percentage of Old Machine usage X missprint percentage	964

<b>From</b>	<b>To</b>	<b>Material</b>	<b>Frequency formula</b>	<b>Frequency</b>
Palette Parking 2	Product storage	Palette (books)	monthly book production of New Machine/ palette capacity	61
Palette Parking 1	Product storage	Palette (books)	monthly book production of Old Machine/ palette capacity	61
Product storage	East Gate	Palette (books)	monthly total book production/ palette capacity	122
East Gate	CD Paper Warehouse	paper	CD paper monthly requirement	240
	HVS Paper Warehouse	paper	HVS paper monthly requirement	146
Input Old Machine	Leftover-paper warehouse	leftover paper	percentage of leftover paper X monthly paper requirement X percentage of Old Machine usage	39
Input New Machine	Leftover-paper warehouse	leftover paper	percentage of leftover paper X monthly paper requirement X percentage of New Machine usage	58

<b>From</b>	<b>To</b>	<b>Material</b>	<b>Frequency formula</b>	<b>Frequency</b>
Missprint Warehouse	East Gate	Palette (missprints)	$\text{total missprints} / \text{palette capacity}$	6



### 4.6.3 Material Handling Cost of Initial Layout

Material transfer cost is cost related to transfer material between departments that occur at certain interval time. For this case, the interval time is one month. Material transfer cost consists of three variables that are transfer cost between department, transfer frequency between department, and distance between departments. Material handling cost calculation based on formula 3.12, for example the material handling cost between Pre-Print to New Machine which employ human transfer:

$$\begin{aligned}
 C_{\text{Pre-Print, New Machine}} &= c_{ij} \times f_{ij} \times d_{ij} \\
 &= 5 \times 23,02 \times 1686 \\
 &= 194038.84
 \end{aligned}$$

The material handling cost calculations of the initial layout are summarized in Table 4.10.

Table 4.10 Material Transfer Cost of Initial Layout

From	To	Distance	Frequency	Conveyance	Handling cost	Total cost
Pre-Print	New Machine	23.02	1686	Human	5	194038.84
	Old Machine	15.40	1124	Human	5	86575.82
Ink warehouse	New Machine	20.94	68	Handlift	20	28478.93
	Old Machine	20.13	46	Handlift	20	18520.36
CD Paper Warehouse	Input New Machine	7.50	168	Forklift	30	37820.99
	Input Old Machine	16.39	72	Forklift	30	35397.81
HVS Paper Warehouse	Input New Machine	8.51	73	Forklift	30	18647.18
	Input Old Machine	25.22	73	Forklift	30	55240.55
Leftover-paper warehouse	Input New Machine	13.46	58	Human	5	3904.24
	Input Old Machine	9.30	39	Human	5	1813.60

From	To	Distance	Frequency	Conveyance	Handling cost	Total cost
Output New Machine	Palette Parking 2	2.50	9084	Human	5	113550.00
	Missprint Warehouse	26.04	868	Human	5	113027.63
Output New Machine	North Gate	4.88	21000	Human	5	512525.05
Output Old Machine	Palette Parking 1	2.50	9084	Human	5	113550.00
	Missprint Warehouse	8.73	964	Human	5	42088.84
Palette Parking 2	Product storage	22.27	61	Handlift	20	27165.55
Palette Parking 1	Product storage	21.11	61	Handlift	20	25752.19
Product storage	East Gate	20.47	122	Handlift	20	49948.19
East Gate	CD Paper Warehouse	18.76	240	Forklift	30	135044.96
	HVS Paper Warehouse	12.08	146	Forklift	30	52920.88

<b>From</b>	<b>To</b>	<b>Distance</b>	<b>Frequency</b>	<b>Conveyance</b>	<b>Handling cost</b>	<b>Total cost</b>
Input Old Machine	Leftover-paper warehouse	9.30	39	Human	5	1813.60
Input New Machine	Leftover-paper warehouse	13.46	58	Human	5	3904.24
Missprint Warehouse	East Gate	41.85	6	Handlift	20	5022.04
<b>TOTAL DISTANCE</b>		<b>363.84</b>		<b>TOTAL COST</b>		<b>1676751.5</b>

#### 4.6.4 Modeling the Problem in Attractor-Repeller Framework

Spreadsheet representation of the model consists of two parts, first is Source Part and second is Processor Part. Source Part consists of departments name, its corresponding centroids, and dimensions. The decision variable lies in Source Part, which is Centroids Column. This is because Processor Part always refers to Source Part, so that any modification in Source Part will directly affect Processor Part. Source Part can be seen in Table 4.11

Table 4.11 Source Part of Model Representation

No	Department Name	Centroid		Dimension	
		X-axis	Y-axis	Length	Width
1	Ink warehouse	-5,5	4,5	5	4
2	CD paper warehouse	-1,25	-6,5	11,5	7
3	HVS paper warehouse	-10,5	-6,5	7	7
4	Leftover paper warehouse	6,5	-6	4	7
5	Pre-print	2,5	9,75	7	6,5
6	Old Machine/input Old Machine	14	-0,5	4	10
7	New Machine	6	-13	15	4
8	Input New Machine	-5	-13	7	4
9	Output Old Machine	16	5	4	1
10	Output New Machine	14	-13	1	4
11	Palette parking 1	14,5	7	1	1
12	Palette parking 2	14	-10,5	1	1

No	Department Name	Centroid		Dimension	
		X-axis	Y-axis	Length	Width
13	Missprint warehouse	12,5	13	8	8
14	Product storage	-5,5	0,25	17	2,5
15	North gate	18,645	-14,5	0,1	5
16	East gate	-17	-16,69	4	0,1

In the Processor Part, first to consider is that all possible connections between two departments are involved to prevent overlap between departments. If any department excluded, the model will recognize current Department of that department as empty Department, so there will be possibility for two departments to completely overlapping. Relation between two columns can be seen in column “From” and “To”.

“ $D_{ij}$ ” column is the Square Distance column in which this column will be divided by Square Target Distance column ( $T_{ij}$ ). Result of this division ( $D_{ij}/T_{ij}$ ) used as “ $z$ ” variable in function  $f(z) = (1/z) - 1$  in column “ $f(z)$ ”. The function  $f(z) = (1/z) - 1$  is implementation of target distance concept in the model. Column “ $c_{ij}$ ” clearly the transfer cost between department and column “ $c_{ij} \times D_{ij}$ ” is the product of transfer cost and Square Distance.

Based on formula 3.11, the objective function to minimize is  $\sum c_{ij}D_{ij} + K \cdot \sum f(z_{ij})$ . This objective function can found at the bottom of the model, which is at Grand Total row.

Table 4.12 Processor Part of Model Representation

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$f(z)$
1	ink warehouse	CD paper warehouse	174,55	4,52	0	0	-0,97
2		HVS paper warehouse	350,79	3,29	0	0	-0,99
3		leftover paper warehouse	119,68	2,38	0	0	-0,98
4		pre-print	91,56	3,15	0	0	-0,97
5		Old Machine/input Old Machine	405,25	2,91	920	551140	-0,99
6		New Machine	438,50	3,73	1360	403420	-0,99
7		input New Machine	306,50	2,38	0	0	-0,99
8		output Old Machine	462,50	1,05	0	0	-1,00
9		output New Machine	686,50	1,05	0	0	-1,00
10		palette parking 1	391,66	0,75	0	0	-1,00
11		palette parking 2	595,51	0,75	0	0	-1,00
12		missprint warehouse	443,73	3,89	0	0	-0,99
13		product storage	159,51	3,02	0	0	-0,98

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
14	ink warehouse	north gate	943,98	0,67	0	0	-1,00
15		east gate	581,05	0,65	0	0	-1,00
16	CD paper warehouse	HVS paper warehouse	44,27	8,56	0	0	-0,81
17		leftover paper warehouse	313,83	7,05	0	0	-0,98
18		pre-print	491,17	8,32	0	0	-0,98
19		Old Machine/input Old Machine	719,57	7,94	2160	1554280,535	-0,99
20		New Machine	361,22	9,26	0	0	-0,97
21		input New Machine	85,58	7,05	5040	431330,3717	-0,92
22		output Old Machine	929,28	4,56	0	0	-1,00
23		output New Machine	713,69	4,56	0	0	-0,99
24		palette parking 1	813,28	3,91	0	0	-1,00
25		palette parking 2	648,22	3,91	0	0	-0,99
26		missprint warehouse	997,27	9,51	0	0	-0,99

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	F(z)
27	CD paper warehouse	product storage	168,82	130,96	8,12	0	0
28		north gate	936,62	997,37	3,73	0	0
29		east gate	35,22	118,79	3,68	7200	855285,9605
30	HVS paper warehouse	leftover paper warehouse	120,66	401,54	3,78	0	0
31		pre-print	542,32	714,18	4,72	0	0
32		Old Machine/input Old Machine	512,29	777,92	4,44	2190	1703640,101
33		New Machine	169,58	278,35	5,44	0	0
34		input New Machine	21,51	32,47	3,78	2190	71109,16495
35		output Old Machine	731,54	1053,87	2,03	0	0
36		output New Machine	435,61	609,17	2,03	0	0
37		palette parking 1	704,27	929,60	1,60	0	0
38		palette parking 2	422,68	567,74	1,60	0	0
39		missprint warehouse	504,88	1181,18	5,63	0	0

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
40	HVS paper warehouse	product storage	142,32	4,57	0	0	-0,97
41		north gate	860,74	1,48	0	0	-1,00
42		east gate	50,13	1,46	4380	219586,4847	-0,97
43	leftover paper warehouse	pre-print	103,42	3,62	0	0	-0,96
44		Old Machine/input Old Machine	93,08	3,37	390	36301,25293	-0,96
45		New Machine	165,29	4,25	0	0	-0,97
46		input New Machine	250,12	2,80	580	145066,7099	-0,99
47		output Old Machine	163,15	1,33	0	0	-0,99
48		output New Machine	255,61	1,33	0	0	-0,99
49		palette parking 1	116,71	0,99	0	0	-0,99
50		palette parking 2	198,93	0,99	0	0	-1,00
51		missprint warehouse	205,36	4,42	0	0	-0,98
52		product storage	71,83	3,49	0	0	-0,95

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
53	leftover paper warehouse	north gate	407,28	0,90	0	0	-1,00
54		east gate	726,20	0,88	0	0	-1,00
55	pre-print	Old Machine/input Old Machine	237,31	4,27	5620	1333696,25	-0,98
56		New Machine	529,81	5,25	8430	4466319,375	-0,99
57		input New Machine	573,81	3,62	0	0	-0,99
58		output Old Machine	204,81	1,91	0	0	-0,99
59		output New Machine	649,81	1,91	0	0	-1,00
60		palette parking 1	171,83	1,50	0	0	-0,99
61		palette parking 2	556,65	1,50	0	0	-1,00
62		missprint warehouse	156,41	5,44	0	0	-0,97
63		product storage	294,61	4,40	0	0	-0,99
64		north gate	848,72	1,39	0	0	-1,00
65		east gate	1079,06	1,36	0	0	-1,00

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
66	Old Machine/input Old Machine	New Machine	220,25	4,95	0	0	-0,98
67		input New Machine	517,25	3,37	0	0	-0,99
68		output Old Machine	34,25	1,73	0	0	-0,95
69		output New Machine	156,25	1,73	0	0	-0,99
70		palette parking 1	20,41	1,34	0	0	-0,93
71		palette parking 2	118,65	1,34	0	0	-0,99
72		missprint warehouse	97,93	5,13	0	0	-0,95
73		product storage	256,78	4,12	0	0	-0,98
74		north gate	217,58	1,24	0	0	-0,99
75		east gate	1222,95	1,21	0	0	-1,00
76		New Machine	input New Machine	121,00	4,25	0	0
77	output Old Machine		424,00	2,37	0	0	-0,99
78	output New Machine		64,00	2,37	0	0	-0,96

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
79	New Machine	palette parking 1	357,94	1,91	0	0	-0,99
80		palette parking 2	52,48	1,91	0	0	-0,96
81		missprint warehouse	580,31	6,20	0	0	-0,99
82		product storage	77,78	5,09	0	0	-0,93
83		north gate	162,15	1,79	0	0	-0,99
84		east gate	542,58	1,75	0	0	-1,00
85		input New Machine	output Old Machine	765,00	1,33	0	0
86	output New Machine		361,00	1,33	0	0	-1,00
87	palette parking 1		661,19	0,99	0	0	-1,00
88	palette parking 2		328,66	0,99	0	0	-1,00
89	missprint warehouse		899,31	4,42	0	0	-1,00
90	product storage		53,88	3,49	0	0	-0,94
91	north gate		561,34	0,90	0	0	-1,00
92	east gate		157,58	0,88	0	0	-0,99

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
93	output Old Machine	output New Machine	328,00	0,40	0	0	-1,00
94		palette parking 1	3,93	0,23	45420	178295,2156	-0,94
95		palette parking 2	276,04	0,23	0	0	-1,00
96		missprint warehouse	19,88	2,50	4820	95830,10666	-0,87
97		product storage	422,36	1,81	0	0	-1,00
98	output Old Machine	north gate	387,25	0,18	0	0	-1,00
99		east gate	1559,24	0,17	0	0	-1,00
100	output New Machine	palette parking 1	289,39	0,23	0	0	-1,00
101		palette parking 2	3,61	0,23	45420	164111,5824	-0,94
102		missprint warehouse	500,31	2,50	4340	2171358,919	-1,00
103		product storage	247,17	1,81	0	0	-0,99
104		north gate	23,83	0,18	105000	2501732,625	-0,99
105		east gate	974,58	0,17	0	0	-1,00
106	palette parking 1	palette parking 2	237,45	0,10	0	0	-1,00

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	$F(z)$
107	palette parking 1	missprint warehouse	28,99	2,03	0	0	-0,93
108		product storage	345,32	1,41	1220	421290,2082	-1,00
109		north gate	361,60	0,07	0	0	-1,00
110		east gate	1406,95	0,07	0	0	-1,00
111	palette parking 2	missprint warehouse	432,14	2,03	0	0	-1,00
112		product storage	203,84	1,41	1220	248686,9869	-0,99
113		north gate	41,17	0,07	0	0	-1,00
114		east gate	931,69	0,07	0	0	-1,00
115	missprint warehouse	product storage	514,52	5,27	0	0	-0,99
116		north gate	581,89	1,90	0	0	-1,00
117		east gate	1701,58	1,86	120	204189,2776	-1,00
118	product storage	north gate	424,10	1,31	0	0	-1,00
119		east gate	360,62	1,28	2440	879902,835	-1,00

No	From	To	$D_{ij}$	$t_{ij}$	$c_{ij}$	$D_{ij} \times c_{ij}$	F(z)
120	north gate	east gate	1275,34	0,04	0	0	-1,00
<b>Total</b>						<b>18636573,96</b>	<b>-295278462, 29</b>
<b>Grand total</b>						<b>-276641888,32</b>	



*\*Complete Representation in Attachments*

### 4.6.5 Solving Model Using Solver

To use Excel 2007 Solver add in to optimize the model, the steps are

1. From Excel 2007 user interface, in tab data, click solver.

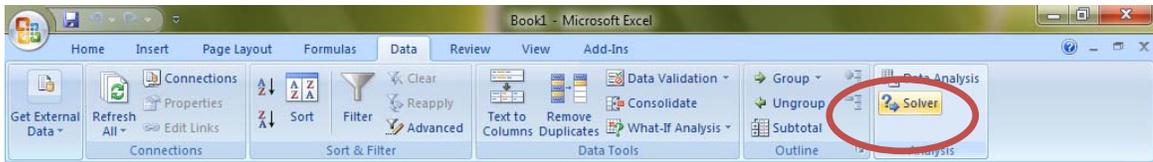


Figure 4.7 Solver Button in Excel 2007 User Interface

2. Dialog window will appear and ask for target cell to optimize. In this case, the target cell is in the Grand Total Row.



Figure 4.8 Target Cell Box in Solver Dialog Window

3. After the target cell to optimize specified, next is to specify the magnitude of optimization, that could be maximize, minimize, or a specific value. In this case, the objective is to minimize the objective function.

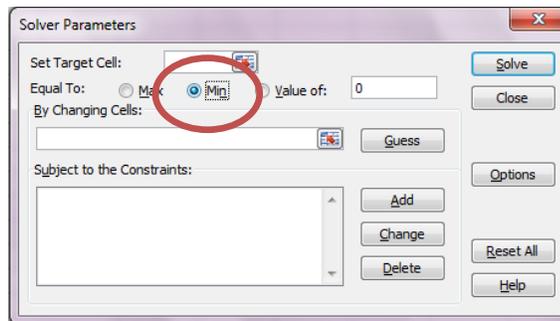


Figure 4.9 Objectives Setting in Solver Dialog Window

4. Next is to specify the bychanging cell, which is the cells that contain the variables.

The variable cells are centroids of Dynamic departments.

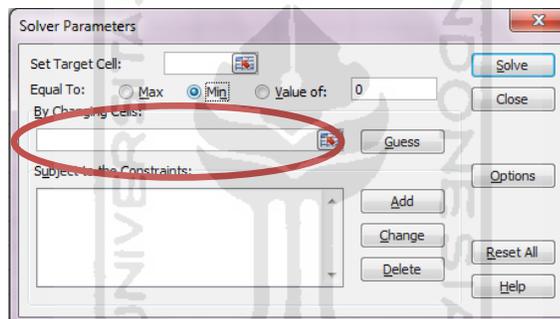


Figure 4.10 Bychanging Cell Box in Solver Dialog Window

5. The constraints added by using add constraints button, then specify each constraints in the dialog window as shown below.

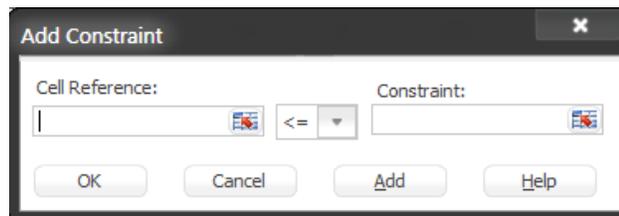


Figure 4.11 Add Constraint Dialog Window

6. Last is to click solve button and let the algorithm search for the best variable that minimize the objective function.

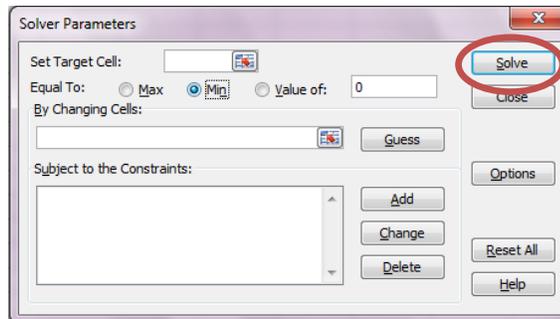


Figure 4.12 Solve Button in Solver Dialog Window

From the experiments, five values of  $\alpha$  were used and the results are:

1. For  $\alpha = 1,5$

Table 4.13 Experiment Result for  $\alpha = 1,5$

No	Department name	Centroid	
		X-axis	Y-axis
1	ink warehouse	-5.50	4.50
2	CD paper warehouse	-14.51	-0.69
3	HVS paper warehouse	-15.50	-11.27
4	leftover paper warehouse	2.01	-2.86
5	pre-print	2.50	9.75
6	Old Machine/input Old Machine	14.00	-0.50
7	New Machine	6.00	-13.00
8	input New Machine	-5.00	-13.00

No	Department name	Centroid	
		X-axis	Y-axis
9	output Old Machine	16.00	5.00
10	output New Machine	14.00	-13.00
11	palette parking 1	11.96	5.95
12	palette parking 2	17.12	-10.68
13	missprint warehouse	15.00	13.00
14	product storage	-15.74	13.74
15	north gate	18.65	-14.50
16	east gate	-17.00	-16.69

This configuration yield an improvement in total transfer cost to 113,72 %, therefore this solution is unfeasible.

2. For  $\alpha = 1,3$

Table 4.14 Experiment Result for  $\alpha = 1,3$

No	Department name	Centroid	
		X-axis	Y-axis
1	ink warehouse	-5.50	4.50
2	CD paper warehouse	-14.51	-0.97
3	HVS paper warehouse	-15.50	-11.37
4	leftover paper warehouse	2.03	-2.84

No	Department name	Centroid	
		X-axis	Y-axis
5	pre-print	2.50	9.75
6	Old Machine/input Old Machine	14.00	-0.50
7	New Machine	6.00	-13.00
8	input New Machine	-5.00	-13.00
9	output Old Machine	16.00	5.00
10	output New Machine	14.00	-13.00
11	palette parking 1	12.14	5.95
12	palette parking 2	16.86	-10.65
13	missprint warehouse	15.00	13.00
14	product storage	-15.74	13.74
15	north gate	18.65	-14.50
16	east gate	-17.00	-16.69

This configuration yield an improvement in total transfer cost to 112,54 %, therefore this solution is unfeasible.

3. For  $\alpha = 1$

Table 4.15 Experiment Result for  $\alpha = 1$

No	Department name	Centroid	
		X-axis	Y-axis
1	ink warehouse	-5,50	4,50
2	CD paper warehouse	-14,51	-3,01
3	HVS paper warehouse	-12,57	-13,50
4	leftover paper warehouse	2,25	-2,58
5	pre-print	2,50	9,75
6	Old Machine/input Old Machine	14,00	-0,50
7	New Machine	6,00	-13,00
8	input New Machine	-5,00	-13,00
9	output Old Machine	16,00	5,00
10	output New Machine	14,00	-13,00
11	palette parking 1	12,44	5,93
12	palette parking 2	16,40	-10,55
13	missprint warehouse	15,00	13,00
14	product storage	-15,74	12,01
15	north gate	18,65	-14,50
16	east gate	-17,00	-16,69

This configuration yield an improvement in total transfer cost to 108, 68 %, therefore this solution is unfeasible.

4. For  $\alpha = 0,1$

Table 4.16 Experiment Result for  $\alpha = 0,1$

No	Department name	Centroid	
		X-axis	Y-axis
1	ink warehouse	-5,50	4,50
2	CD paper warehouse	-12,03	-6,99
3	HVS paper warehouse	-10,68	-13,50
4	leftover paper warehouse	4,36	-0,25
5	pre-print	2,50	9,75
6	Old Machine/input Old Machine	14,00	-0,50
7	New Machine	6,00	-13,00
8	input New Machine	-5,00	-13,00
9	output Old Machine	16,00	5,00
10	output New Machine	14,00	-13,00
11	palette parking 1	14,28	4,01
12	palette parking 2	13,05	-11,35
13	missprint warehouse	15,00	9,35
14	product storage	-0,59	-7,13
15	north gate	18,65	-14,50

No	Department name	Centroid	
		X-axis	Y-axis
16	east gate	-17,00	-16,69

This configuration yield an improvement in total transfer cost to 91, 07%. The corresponding approximated layout is as Figure 4.13.

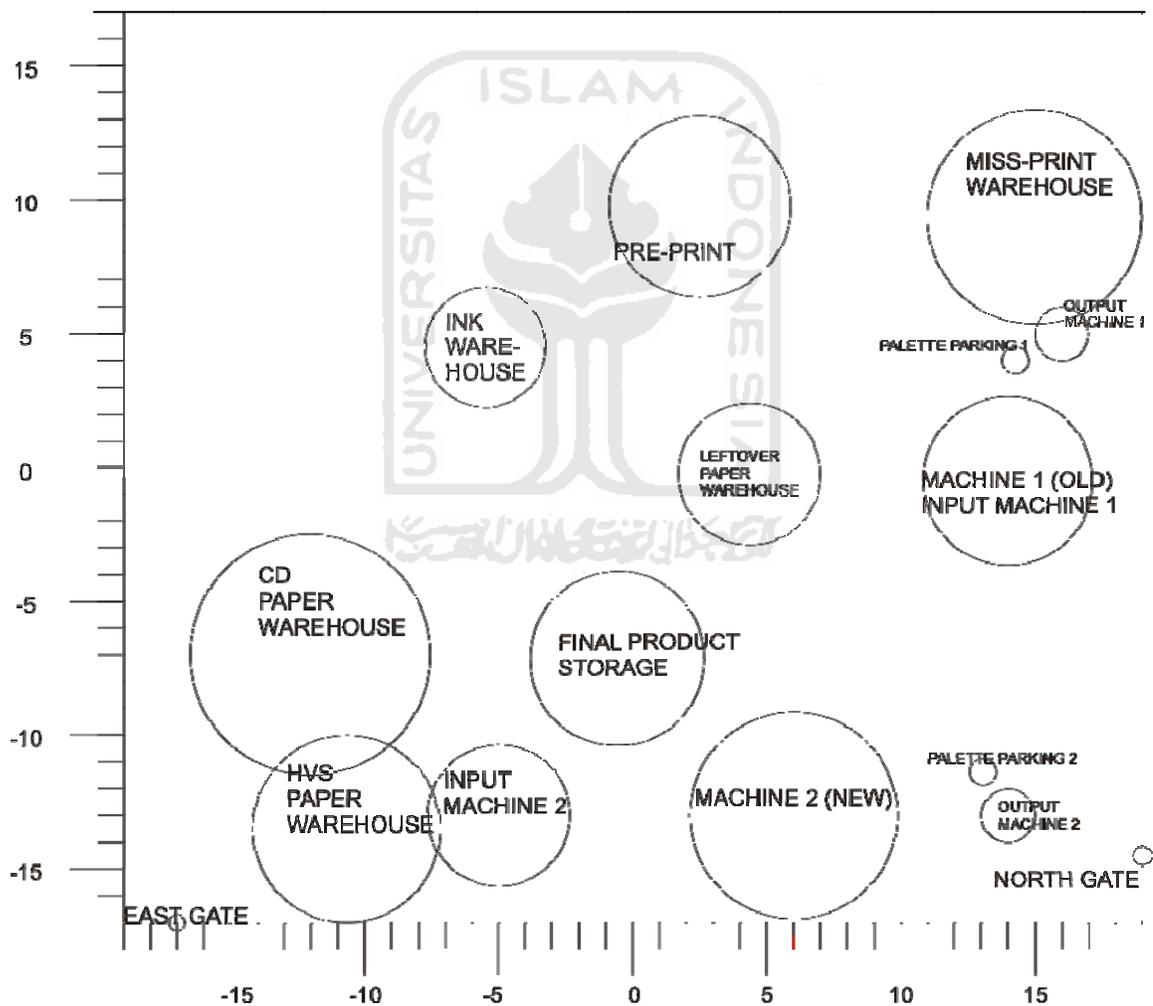


Figure 4.13 Circle Approximated of Improved Layout for  $\alpha = 0,1$

5. For  $\alpha = 0,01$

Table 4.17 Experiment Result for  $\alpha = 0,01$

No	Department name	Centroid	
		X-axis	Y-axis
1	ink warehouse	-5,50	4,50
2	CD paper warehouse	-10,14	-12,51
3	HVS paper warehouse	-6,28	-9,01
4	leftover paper warehouse	2,97	-4,57
5	pre-print	2,50	9,75
6	Old Machine/input Old Machine	14,00	-0,50
7	New Machine	6,00	-13,00
8	input New Machine	-5,00	-13,00
9	output Old Machine	16,00	5,00
10	output New Machine	14,00	-13,00
11	palette parking 1	14,84	4,99
12	palette parking 2	13,02	-13,25
13	missprint warehouse	10,84	1,11
14	product storage	-0,19	-10,11
15	north gate	18,65	-14,50
16	east gate	-17,00	-16,69

This configuration yield an improvement in total transfer cost to 82, 99%. The corresponding approximated layout is as Figure 4.14.

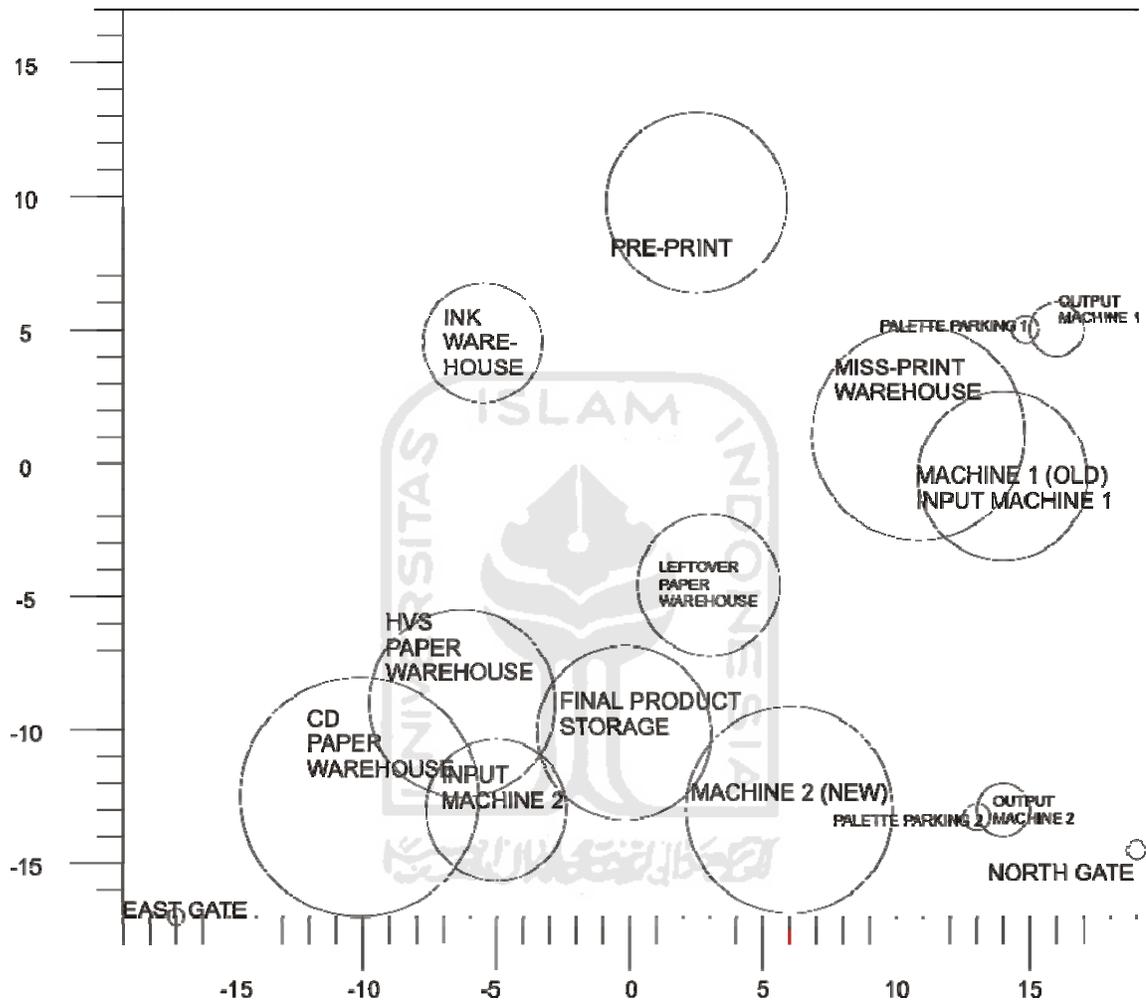


Figure 4.14 Circle Approximated of Improved Layout for  $\alpha = 0,01$

#### 4.6.6 Performance of Attractor Repeller Approach

Experiments of varying value of  $\alpha$  from 1.5, 1.3, 1, 0.1, and 0.01 yield two feasible layout configuration, that are at experiment using  $\alpha$  equal 0,1 and 0,01. Based on the fact that every improvement occurs required some overlap, this is necessary to analyze the amount

of overlap compare to the improvements. At  $\alpha = 1$ , its clear that amount of overlap can be defined as the values of  $f(z)$  which are higher than zero. In every experiment, we need to change back value of  $\alpha$  after optimization to see the real overlap. Table 4.18 below summarizes the comparison.

Table 4.18 Attractor Repeller performance

$\alpha$	Improvement	Overlap
1,5	-13,72 %	0
1,3	-12,54 %	0
1	-8,68 %	0
0,1	8.93%	1.35
0,01	17.01%	10.29

## CHAPTER V

### DISCUSSION AND ANALYSIS

The purpose of research is to analyze performance of Attractors-Repeller approach for facility layout design. Five experiments by varying value of  $\alpha$  conducted and corresponding proportion of material handling cost improvement compare to the overlap noted.

#### 5.1 Attractor Repeller Behavior

Based on experiment, the Attractor Repeller approaches succeed to provide improvement only when overlap occurs. At  $\alpha$  equal 1.5 there is no overlap but also there is no positive improvement. As can be seen in Table 4.18, at  $\alpha$  equal 1.5, the improvement is -13.72%. This condition also apply for  $\alpha$  equal 1.3 and 1 but with better improvement that is -12.54% and -8.68% respectively. Positive improvement starts to show when using  $\alpha$  smaller than one. At  $\alpha$  equal 0.1, positive improvement as much as 8.93% gained but as the consequence, there is overlap as much as 1.35. Bigger improvement provided by  $\alpha$  equal 0.01 that is 17.01% with 10.29 overlap.

The trend of increasing overlap as the improvement increase, lead to ambiguity for the next step when circle layout converts back into real layout. Presence of overlap will cause the overlapped departments push away to an unknown point without clear, exact guidance.

## 5.2 Cause of Overlap

Although calculations in the model did not indicate the occurrence of overlap when smaller value of  $\alpha$  used, but actually there are some overlap when plotting the circle to the layout. This is because assumption of target distance when value of  $\alpha$  reduced is smaller. See the illustration below:

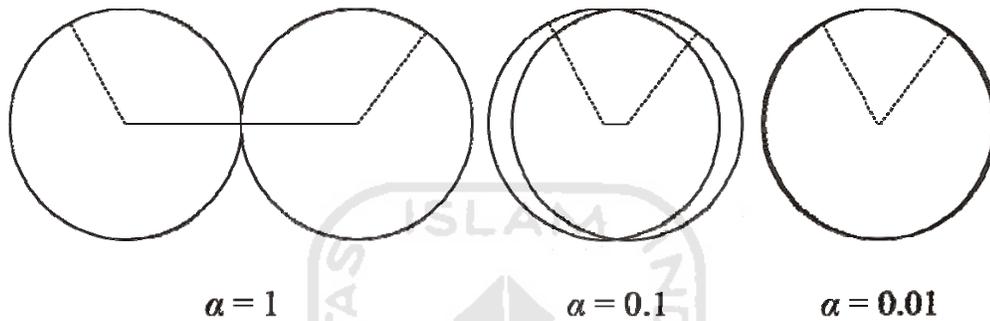


Figure 5.1 Target Distance Assumption

Despite downsizing  $\alpha$  value is intended to give flexibility for the optimization algorithm to find the best centre position so that smaller  $\alpha$  value can result in better distance depreciation, but overlap will be greater.

## CHAPTER VI

### CONCLUSION AND SUGGESTION

#### 6.1 Conclusion

After analyzing the performance of Attractors-Repeller approach for facility layout design some conclusions are:

1. In this case study, Attractors-Repeller approach succeeds to provide improvement only when overlap occurs. There is a trend in where increase in improvement lead to increase number of overlap. Overlap lead to ambiguity for the next step when circle layout converts back into real layout.
2. From the analysis, it can be said that Attractors-Repeller approach unsuitable for the case study.
3. Attractors-Repeller approach become unsuitable is generally because the presence of overlap. Overlap occurs because assumption of target distance when value of  $\alpha$  reduced is smaller.

#### 6.2 Recommendation

For further research, it may useful to analyze proportion or ratio between fraction of improvement and fraction of overlap. Those kind of ratio will help to choose appropriate value of  $\alpha$  which will give best possible improvement regarding its overlap.

Varying number and initial position of fixed department also necessary to find out how reliable this approach to overcome various kind of facility layout problem. Its because the number and initial position of fixed department in this case study seems to block up optimal ability of the approach.



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## APPENDIX

1. Attractor Repeller model with  $\alpha = 1.5$
2. Attractor Repeller model with  $\alpha = 1.3$
3. Attractor Repeller model with  $\alpha = 1$
4. Attractor Repeller model with  $\alpha = 0.1$
5. Attractor Repeller model with  $\alpha = 0.01$



1. Source part of Attractor Repeller model with  $\alpha = 1.5$

No	Department	Dimension		Centroid	
		li	wi	xi	yi
1	ink warehouse	5	4	-5.50	4.50
2	CD paper warehouse	11.5	7	-14.51	-0.69
3	HVS paper warehouse	7	7	-15.50	-11.27
4	leftover paper warehouse	4	7	2.01	-2.86
5	pre-print	7	6.5	2.50	9.75
6	machine 1/input machine 1	4	10	14.00	-0.50
7	machine 2	15	4	6.00	-13.00
8	input machine 2	7	4	-5.00	-13.00
9	output machine 1	4	1	16.00	5.00
10	output machine 2	1	4	14.00	-13.00
11	palette parking 1	1	1	11.96	5.95
12	palette parking 2	1	1	17.12	-10.68
13	missprint warehouse	8	8	15.00	13.00
14	product storage	17	2.5	-15.74	13.74
15	north gate	0.1	5	18.65	-14.50
16	east gate	4	0.1	-17.00	-16.69

2. Source part of Attractor Repeller model with  $\alpha = 1.3$

No	Department	Dimension		Centroid	
		li	wi		
1	ink warehouse	5	4	-5.50	4.50
2	CD paper warehouse	11.5	7	-14.51	-0.97
3	HVS paper warehouse	7	7	-15.50	-11.37
4	leftover paper warehouse	4	7	2.03	-2.84
5	pre-print	7	6.5	2.50	9.75
6	machine 1/input machine 1	4	10	14.00	-0.50
7	machine 2	15	4	6.00	-13.00
8	input machine 2	7	4	-5.00	-13.00
9	output machine 1	4	1	16.00	5.00
10	output machine 2	1	4	14.00	-13.00
11	palette parking 1	1	1	12.14	5.95
12	palette parking 2	1	1	16.86	-10.65
13	missprint warehouse	8	8	15.00	13.00
14	product storage	17	2.5	-15.74	13.74
15	north gate	0.1	5	18.65	-14.50
16	east gate	4	0.1	-17.00	-16.69

3. Source part of Attractor Repeller model with  $\alpha = 1$

No	Department	Dimension		Centroid	
		li	wi		
1	ink warehouse	5	4	-5.50	4.50
2	CD paper warehouse	11.5	7	-14.51	-3.01
3	HVS paper warehouse	7	7	-12.57	-13.50
4	leftover paper warehouse	4	7	2.25	-2.58
5	pre-print	7	6.5	2.50	9.75
6	machine 1/input machine 1	4	10	14.00	-0.50
7	machine 2	15	4	6.00	-13.00
8	input machine 2	7	4	-5.00	-13.00
9	output machine 1	4	1	16.00	5.00
10	output machine 2	1	4	14.00	-13.00
11	palette parking 1	1	1	12.44	5.93
12	palette parking 2	1	1	16.40	-10.55
13	missprint warehouse	8	8	15.00	13.00
14	product storage	17	2.5	-15.74	12.01
15	north gate	0.1	5	18.65	-14.50
16	east gate	4	0.1	-17.00	-16.69

4. Source part of Attractor Repeller model with  $\alpha = 0.1$

No	Department	Dimension		Centroid	
		li	wi		
1	ink warehouse	5	4	-5.50	4.50
2	CD paper warehouse	11.5	7	-12.03	-6.99
3	HVS paper warehouse	7	7	-10.68	-13.50
4	leftover paper warehouse	4	7	4.36	-0.25
5	pre-print	7	6.5	2.50	9.75
6	machine 1/input machine 1	4	10	14.00	-0.50
7	machine 2	15	4	6.00	-13.00
8	input machine 2	7	4	-5.00	-13.00
9	output machine 1	4	1	16.00	5.00
10	output machine 2	1	4	14.00	-13.00
11	palette parking 1	1	1	14.28	4.01
12	palette parking 2	1	1	13.05	-11.35
13	missprint warehouse	8	8	15.00	9.35
14	product storage	17	2.5	-0.59	-7.13
15	north gate	0.1	5	18.65	-14.50
16	east gate	4	0.1	-17.00	-16.69

5. Source part of Attractor Repeller model with  $\alpha = 0.01$

No	Department	Dimension		Centroid	
		li	wi		
1	ink warehouse	5	4	-5.50	4.50
2	CD paper warehouse	11.5	7	-10.14	-12.51
3	HVS paper warehouse	7	7	-6.28	-9.01
4	leftover paper warehouse	4	7	2.97	-4.57
5	pre-print	7	6.5	2.50	9.75
6	machine 1/input machine 1	4	10	14.00	-0.50
7	machine 2	15	4	6.00	-13.00
8	input machine 2	7	4	-5.00	-13.00
9	output machine 1	4	1	16.00	5.00
10	output machine 2	1	4	14.00	-13.00
11	palette parking 1	1	1	14.84	4.99
12	palette parking 2	1	1	13.02	-13.25
13	missprint warehouse	8	8	10.84	1.11
14	product storage	17	2.5	-0.19	-10.11
15	north gate	0.1	5	18.65	-14.50
16	east gate	4	0.1	-17.00	-16.69

no	α=	1,5	in euclidean				dimension				modules radi	target dist	distance(Dij)	cost(cij)	Dij x cij	repeller function(f)	
			from		to		from		to								
			from	to	x-axis	y-axis	length	width	length	width							
1	ink warehouse	CD paper warehouse	-5,50	4,50	-14,51	-0,69	5	4	11,5	7	2,24	4,49	67,78	108,20	0,00	0	-0,37
2		HVS paper warehouse	-5,50	4,50	-15,50	-11,27	5	4	7	7	2,24	3,50	49,35	348,67	0,00	0	-0,86
3		leftover paper warehouse	-5,50	4,50	2,01	-2,86	5	4	4	7	2,24	2,65	35,75	110,54	0,00	0	-0,68
4		pre-print	-5,50	4,50	2,50	9,75	5	4	7	6,5	2,24	3,37	47,19	91,56	0	0	-0,48
5		machine 1/input machine 1	-5,50	4,50	14,00	-0,50	5	4	4	10	2,24	3,16	43,71	405,25	920,00	551140	-0,89
6		machine 2	-5,50	4,50	6,00	-13,00	5	4	15	4	2,24	3,87	55,98	438,50	1360,00	403420	-0,87
7		input machine 2	-5,50	4,50	-5,00	-13,00	5	4	7	4	2,24	2,65	35,75	306,50	0,00	0	-0,88
8		output machine 1	-5,50	4,50	16,00	5,00	5	4	4	1	2,24	1,00	15,71	462,50	0,00	0	-0,97
9		output machine 2	-5,50	4,50	14,00	-13,00	5	4	1	4	2,24	1,00	15,71	686,50	0,00	0	-0,98
10		palette parking 1	-5,50	4,50	11,96	5,95	5	4	1	1	2,24	0,50	11,23	306,91	0,00	0	-0,96
11		palette parking 2	-5,50	4,50	17,12	-10,68	5	4	1	1	2,24	0,50	11,23	741,83	0,00	0	-0,98
12		missprint warehouse	-5,50	4,50	15,00	13,00	5	4	8	8	2,24	4,00	58,33	492,50	0,00	0	-0,88
13		product storage	-5,50	4,50	-15,74	13,74	5	4	17	2,5	2,24	3,26	45,30	190,25	0,00	0	-0,76
14		north gate	-5,50	4,50	18,65	-14,50	5	4	0,1	5	2,24	0,35	10,06	943,98	0,00	0	-0,99
15		east gate	-5,50	4,50	-17,00	-16,69	5	4	4	0,1	2,24	0,32	9,77	581,05	0,00	0	-0,98
16	CD paper warehouse	HVS paper warehouse	-14,51	-0,69	-15,50	-11,27	11,5	11,5	7	7	5,75	3,50	128,34	112,87	0,00	0	0,14
17		leftover paper warehouse	-14,51	-0,69	2,01	-2,86	11,5	11,5	4	7	5,75	2,65	105,73	277,79	0,00	0	-0,62
18		pre-print	-14,51	-0,69	2,50	9,75	11,5	11,5	7	6,5	5,75	3,37	124,84	398,50	0,00	0	-0,69
19		machine 1/input machine 1	-14,51	-0,69	14,00	-0,50	11,5	11,5	4	10	5,75	3,16	119,14	813,08	2160,00	1756252,205	-0,85
20		machine 2	-14,51	-0,69	6,00	-13,00	11,5	11,5	15	4	5,75	3,87	138,90	572,32	0,00	0	-0,76
21		input machine 2	-14,51	-0,69	-5,00	-13,00	11,5	11,5	7	4	5,75	2,65	105,73	242,02	5040,00	1219759,635	-0,56
22		output machine 1	-14,51	-0,69	16,00	5,00	11,5	11,5	4	1	5,75	1,00	68,34	963,49	0,00	0	-0,93
23		output machine 2	-14,51	-0,69	14,00	-13,00	11,5	11,5	1	4	5,75	1,00	68,34	964,54	0,00	0	-0,93
24		palette parking 1	-14,51	-0,69	11,96	5,95	11,5	11,5	1	1	5,75	0,50	58,59	744,91	0,00	0	-0,92
25		palette parking 2	-14,51	-0,69	17,12	-10,68	11,5	11,5	1	1	5,75	0,50	58,59	1100,16	0,00	0	-0,95
26		missprint warehouse	-14,51	-0,69	15,00	13,00	11,5	11,5	8	8	5,75	4,00	142,59	1058,53	0,00	0	-0,87
27		product storage	-14,51	-0,69	-15,74	13,74	11,5	11,5	17	2,5	5,75	3,26	121,76	209,78	0,00	0	-0,42
28		north gate	-14,51	-0,69	18,65	-14,50	11,5	11,5	0,1	5	5,75	0,35	55,88	1290,19	0,00	0	-0,96
29		east gate	-14,51	-0,69	-17,00	-16,69	11,5	11,5	4	0,1	5,75	0,32	55,20	261,98	7200,00	1886223,32	-0,79
30	HVS paper warehouse	leftover paper warehouse	-15,50	-11,27	2,01	-2,86	7	7	4	7	3,50	2,65	56,66	377,47	0,00	0	-0,85
31		pre-print	-15,50	-11,27	2,50	9,75	7	7	7	6,5	3,50	3,37	70,85	765,82	0,00	0	-0,91
32		machine 1/input machine 1	-15,50	-11,27	14,00	-0,50	7	7	4	10	3,50	3,16	66,58	986,23	2190,00	2159844,728	-0,93
33		machine 2	-15,50	-11,27	6,00	-13,00	7	7	15	4	3,50	3,87	81,54	465,24	0,00	0	-0,82
34		input machine 2	-15,50	-11,27	-5,00	-13,00	7	7	7	4	3,50	2,65	56,66	113,24	2190,00	248006,3246	-0,50
35		output machine 1	-15,50	-11,27	16,00	5,00	7	7	4	1	3,50	1,00	30,38	1256,94	0,00	0	-0,98
36		output machine 2	-15,50	-11,27	14,00	-13,00	7	7	1	4	3,50	1,00	30,38	873,24	0,00	0	-0,97
37		palette parking 1	-15,50	-11,27	11,96	5,95	7	7	1	1	3,50	0,50	24,00	1050,49	0,00	0	-0,98
38		palette parking 2	-15,50	-11,27	17,12	-10,68	7	7	1	1	3,50	0,50	24,00	1064,14	0,00	0	-0,98
39		missprint warehouse	-15,50	-11,27	15,00	13,00	7	7	8	8	3,50	4,00	84,38	1519,25	0,00	0	-0,94
40		product storage	-15,50	-11,27	-15,74	13,74	7	7	17	2,5	3,50	3,26	68,54	625,55	0,00	0	-0,89
41		north gate	-15,50	-11,27	18,65	-14,50	7	7	0,1	5	3,50	0,35	22,27	1176,32	0,00	0	-0,98
42		east gate	-15,50	-11,27	-17,00	-16,69	7	7	4	0,1	3,50	0,32	21,85	31,58	4380,00	138313,7219	-0,31
43	leftover paper warehouse	pre-print	2,01	-2,86	2,50	9,75	4	7	7	6,5	2,65	3,37	54,33	159,14	0,00	0	-0,66
44		machine 1/input machine 1	2,01	-2,86	14,00	-0,50	4	7	4	10	2,65	3,16	50,60	149,26	390,00	58210,76657	-0,66
45		machine 2	2,01	-2,86	6,00	-13,00	4	7	15	4	2,65	3,87	63,74	118,81	0,00	0	-0,46
46		input machine 2	2,01	-2,86	-5,00	-13,00	4	7	7	4	2,65	2,65	42,00	152,08	580,00	88205,78156	-0,72
47		output machine 1	2,01	-2,86	16,00	5,00	4	7	4	1	2,65	1,00	19,94	257,37	0,00	0	-0,92
48		output machine 2	2,01	-2,86	14,00	-13,00	4	7	1	4	2,65	1,00	19,94	246,62	0,00	0	-0,92
49		palette parking 1	2,01	-2,86	11,96	5,95	4	7	1	1	2,65	0,50	14,84	176,47	0,00	0	-0,92
50		palette parking 2	2,01	-2,86	17,12	-10,68	4	7	1	1	2,65	0,50	14,84	289,30	0,00	0	-0,95
51		missprint warehouse	2,01	-2,86	15,00	13,00	4	7	8	8	2,65	4,00	66,25	420,08	0,00	0	-0,84
52		product storage	2,01	-2,86	-15,74	13,74	4	7	17	2,5	2,65	3,26	52,31	590,58	0,00	0	-0,91
53		north gate	2,01	-2,86	18,65	-14,50	4	7	0,1	5	2,65	0,35	13,49	412,25	0,00	0	-0,97
54		east gate	2,01	-2,86	-17,00	-16,69	4	7	4	0,1	2,65	0,32	13,16	552,71	0,00	0	-0,98
55	pre-print	machine 1/input machine 1	2,50	9,75	14,00	-0,50	7	6,5	4	10	3,37	3,16	64,06	237,31	5620,00	1333696,25	-0,73
56		machine 2	2,50	9,75	6,00	-13,00	7	6,5	15	4	3,37	3,87	78,75	529,81	8430,00	4466319,375	-0,85
57		input machine 2	2,50	9,75	-5,00	-13,00	7	6,5	7	4	3,37	2,65	54,33	573,81	0,00	0	-0,91
58		output machine 1	2,50	9,75	16,00	5,00	7	6,5	4	1	3,37	1,00	28,68	204,81	0,00	0	-0,86
59		output machine 2	2,50	9,75	14,00	-13,00	7	6,5	1	4	3,37	1,00	28,68	649,81	0,00	0	-0,96
60		palette parking 1	2,50	9,75	11,96	5,95	7	6,5	1	1	3,37	0,50	22,50	103,90	0,00	0	-0,78
61		palette parking 2	2,50	9,75	17,12	-10,68	7	6,5	1	1	3,37	0,50	22,50	630,91	0,00	0	-0,96
62		missprint warehouse	2,50	9,75	15,00	13,00	7	6,5	8	8	3,37	4,00	81,53	166,81	0,00	0	-0,51
63		product storage	2,50	9,75	-15,74	13,74	7	6,5	17	2,5	3,37	3,26	65,98	348,64	0,00	0	-0,81
64		north gate	2,50	9,75	18,65	-14,50	7	6,5	0,1	5	3,37	0,35	20,83	848,72	0,00	0	-0,98
65		east gate	2,50	9,75	-17,00	-16,69	7	6,5	4	0,1	3,37	0,32	20,41	1079,06	0,00	0	-0,98
66	machine 1/input machine 1	machine 2	14,00	-0,50	6,00	-13,00	4	10	15	4	3,16	3,87	74,24	220,25	0,00	0	-0,66
67		input machine 2	14,00	-0,50	-5,00	-13,00	4	10	7	4	3,16	2,65	50,60	517,25	0,00	0	-0,90
68		output machine 1	14,00	-0,50	16,00	5,00	4	10	4	1	3,16	1,00	25,99	34,25	0,00	0	-0,24
69		output machine 2	14,00	-0,50	14,00	-13,00	4	10	1	4	3,16	1,00	25,99	156,25	0,00	0	-0,83
70		palette parking 1	14,00	-0,50	11,96	5,95	4	10	1	1	3,16	0,50	20,12	45,77	0,00	0	-0,56
71		palette parking 2	14,00	-0,50	17,12	-10,68	4	10	1	1	3,16	0,50	20,12	113,29	0,00	0	-0,82
72		missprint warehouse	14,00	-0,50	15,00	13,00	4	10	8	8	3,16	4,00	76,95	183,25	0,00	0	-0,58
73		product storage	14,00	-0,50	-15,74	13,74	4	10	17	2,5	3,16	3,26	61,86	1087,28	0,00	0	-0,94
74		north gate	14,00	-0,50	18,65	-14,50	4	10	0,1	5	3,16	0,35	18,54	217,58	0,00	0	-0,91
75		east gate	14,00	-0,50	-17,00	-16,69	4	10	4	0,1	3,16	0,32	18,15	1222,95	0,00	0	-0,99
76	machine 2	input machine 2	6,00	-13,00	-5,00	-13,00	15	4	7	4	3,87	2,65	63,74	121,00	0,00	0	-0,47
77		output machine 1	6,00	-13,00	16,00	5,00	15	4	4	1	3,87	1,00	35,62	424,00	0,00	0	-0,92
78		output machine 2	6,00	-13,00	14,00	-13,00	15	4	1	4	3,87	1,00	35,62	64,00	0,00	0	-0,44
79		palette parking 1	6,00	-13,00	11,96	5,95	15	4									

no	α-	to	in euclidean				dimension				modules radi	target dist	distance(Dij)	cost(cij)	Dij x cij	repeller function(f)	
			from		to		from		to								
			x-axis	y-axis	x-axis	y-axis	length	width	length	width							
1	ink warehouse	CD paper warehouse	-5,50	4,50	-14,51	-0,97	5	4	11,5	7	2,24	4,49	58,74	111,20	0,00	0	-0,47
2		HVS paper warehouse	-5,50	4,50	-15,50	-11,37	5	4	7	7	2,24	3,50	42,77	351,71	0,00	0	-0,88
3		leftover paper warehouse	-5,50	4,50	2,03	-2,84	5	4	4	7	2,24	2,65	30,98	110,59	0,00	0	-0,72
4		pre-print	-5,50	4,50	2,50	9,75	5	4	7	6,5	2,24	3,37	40,90	91,56	0	0	-0,55
5		machine 1/input machine 1	-5,50	4,50	14,00	-0,50	5	4	4	10	2,24	3,16	37,88	405,25	920,00	551140	-0,91
6		machine 2	-5,50	4,50	6,00	-13,00	5	4	15	4	2,24	3,87	48,52	438,50	1360,00	403420	-0,89
7		input machine 2	-5,50	4,50	-5,00	-13,00	5	4	7	4	2,24	2,65	30,98	306,50	0,00	0	-0,90
8		output machine 1	-5,50	4,50	16,00	5,00	5	4	4	1	2,24	1,00	13,61	462,50	0,00	0	-0,97
9		output machine 2	-5,50	4,50	14,00	-13,00	5	4	1	4	2,24	1,00	13,61	686,50	0,00	0	-0,98
10		palette parking 1	-5,50	4,50	12,14	5,95	5	4	1	1	2,24	0,50	9,73	313,11	0,00	0	-0,97
11		palette parking 2	-5,50	4,50	16,86	-10,65	5	4	1	1	2,24	0,50	9,73	729,70	0,00	0	-0,99
12		missprint warehouse	-5,50	4,50	15,00	13,00	5	4	8	8	2,24	4,00	50,56	492,50	0,00	0	-0,90
13		product storage	-5,50	4,50	-15,74	13,74	5	4	17	2,5	2,24	3,26	39,26	190,25	0,00	0	-0,79
14		north gate	-5,50	4,50	18,65	-14,50	5	4	0,1	5	2,24	0,35	8,72	943,98	0,00	0	-0,99
15		east gate	-5,50	4,50	-17,00	-16,69	5	4	4	0,1	2,24	0,32	8,47	581,05	0,00	0	-0,99
16	CD paper warehouse	HVS paper warehouse	-14,51	-0,97	-15,50	-11,37	11,5	11,5	7	7	5,75	3,50	111,23	108,99	0,00	0	0,02
17		leftover paper warehouse	-14,51	-0,97	2,03	-2,84	11,5	11,5	4	7	5,75	2,65	91,64	277,22	0,00	0	-0,67
18		pre-print	-14,51	-0,97	2,50	9,75	11,5	11,5	7	6,5	5,75	3,37	108,19	404,44	0,00	0	-0,73
19		machine 1/input machine 1	-14,51	-0,97	14,00	-0,50	11,5	11,5	4	10	5,75	3,16	103,26	813,27	2160,00	1756654,894	-0,87
20		machine 2	-14,51	-0,97	6,00	-13,00	11,5	11,5	15	4	5,75	3,87	120,38	565,49	0,00	0	-0,79
21		input machine 2	-14,51	-0,97	-5,00	-13,00	11,5	11,5	7	4	5,75	2,65	91,64	235,18	5040,00	1185307,252	-0,61
22		output machine 1	-14,51	-0,97	16,00	5,00	11,5	11,5	4	1	5,75	1,00	59,23	966,77	0,00	0	-0,94
23		output machine 2	-14,51	-0,97	14,00	-13,00	11,5	11,5	1	4	5,75	1,00	59,23	957,71	0,00	0	-0,94
24		palette parking 1	-14,51	-0,97	12,14	5,95	11,5	11,5	1	1	5,75	0,50	50,78	758,08	0,00	0	-0,93
25		palette parking 2	-14,51	-0,97	16,86	-10,65	11,5	11,5	1	1	5,75	0,50	50,78	1078,23	0,00	0	-0,95
26		missprint warehouse	-14,51	-0,97	15,00	13,00	11,5	11,5	8	8	5,75	4,00	123,58	1066,30	0,00	0	-0,88
27		product storage	-14,51	-0,97	-15,74	13,74	11,5	11,5	17	2,5	5,75	3,26	105,52	217,97	0,00	0	-0,52
28		north gate	-14,51	-0,97	18,65	-14,50	11,5	11,5	0,1	5	5,75	0,35	48,43	1282,51	0,00	0	-0,96
29		east gate	-14,51	-0,97	-17,00	-16,69	11,5	11,5	4	0,1	5,75	0,32	47,84	253,07	7200,00	1822100,547	-0,81
30	HVS paper warehouse	leftover paper warehouse	-15,50	-11,37	2,03	-2,84	7	7	4	7	3,50	2,65	49,10	380,02	0,00	0	-0,87
31		pre-print	-15,50	-11,37	2,50	9,75	7	7	7	6,5	3,50	3,37	61,40	769,86	0,00	0	-0,92
32		machine 1/input machine 1	-15,50	-11,37	14,00	-0,50	7	7	4	10	3,50	3,16	57,70	988,31	2190,00	2164396,535	-0,94
33		machine 2	-15,50	-11,37	6,00	-13,00	7	7	15	4	3,50	3,87	70,67	464,92	0,00	0	-0,85
34		input machine 2	-15,50	-11,37	-5,00	-13,00	7	7	7	4	3,50	2,65	49,10	112,92	2190,00	247298,3387	-0,57
35		output machine 1	-15,50	-11,37	16,00	5,00	7	7	4	1	3,50	1,00	26,33	1260,08	0,00	0	-0,98
36		output machine 2	-15,50	-11,37	14,00	-13,00	7	7	1	4	3,50	1,00	26,33	872,92	0,00	0	-0,97
37		palette parking 1	-15,50	-11,37	12,14	5,95	7	7	1	1	3,50	0,50	20,80	1063,49	0,00	0	-0,98
38		palette parking 2	-15,50	-11,37	16,86	-10,65	7	7	1	1	3,50	0,50	20,80	1047,91	0,00	0	-0,98
39		missprint warehouse	-15,50	-11,37	15,00	13,00	7	7	8	8	3,50	4,00	73,13	1523,93	0,00	0	-0,95
40		product storage	-15,50	-11,37	-15,74	13,74	7	7	17	2,5	3,50	3,26	59,40	630,36	0,00	0	-0,91
41		north gate	-15,50	-11,37	18,65	-14,50	7	7	0,1	5	3,50	0,35	19,30	1175,71	0,00	0	-0,98
42		east gate	-15,50	-11,37	-17,00	-16,69	7	7	4	0,1	3,50	0,32	18,93	30,55	4380,00	133796,5762	-0,38
43	leftover paper warehouse	pre-print	2,03	-2,84	2,50	9,75	4	7	7	6,5	2,65	3,37	47,09	158,72	0,00	0	-0,70
44		machine 1/input machine 1	2,03	-2,84	14,00	-0,50	4	7	4	10	2,65	3,16	43,85	148,74	390,00	58007,06	-0,71
45		machine 2	2,03	-2,84	6,00	-13,00	4	7	15	4	2,65	3,87	55,24	118,98	0,00	0	-0,54
46		input machine 2	2,03	-2,84	-5,00	-13,00	4	7	7	4	2,65	2,65	36,40	152,66	580,00	88544,02656	-0,76
47		output machine 1	2,03	-2,84	16,00	5,00	4	7	4	1	2,65	1,00	17,28	256,60	0,00	0	-0,93
48		output machine 2	2,03	-2,84	14,00	-13,00	4	7	1	4	2,65	1,00	17,28	246,49	0,00	0	-0,93
49		palette parking 1	2,03	-2,84	12,14	5,95	4	7	1	1	2,65	0,50	12,86	179,34	0,00	0	-0,93
50		palette parking 2	2,03	-2,84	16,86	-10,65	4	7	1	1	2,65	0,50	12,86	281,04	0,00	0	-0,95
51		missprint warehouse	2,03	-2,84	15,00	13,00	4	7	8	8	2,65	4,00	57,42	419,10	0,00	0	-0,86
52		product storage	2,03	-2,84	-15,74	13,74	4	7	17	2,5	2,65	3,26	45,34	590,72	0,00	0	-0,92
53		north gate	2,03	-2,84	18,65	-14,50	4	7	0,1	5	2,65	0,35	11,69	411,99	0,00	0	-0,97
54		east gate	2,03	-2,84	-17,00	-16,69	4	7	4	0,1	2,65	0,32	11,41	553,86	0,00	0	-0,98
55	pre-print	machine 1/input machine 1	2,50	9,75	14,00	-0,50	7	6,5	4	10	3,37	3,16	55,52	237,31	5620,00	1333696,25	-0,77
56		machine 2	2,50	9,75	6,00	-13,00	7	6,5	15	4	3,37	3,87	68,25	529,81	8430,00	4466319,375	-0,87
57		input machine 2	2,50	9,75	-5,00	-13,00	7	6,5	7	4	3,37	2,65	47,09	573,81	0,00	0	-0,92
58		output machine 1	2,50	9,75	16,00	5,00	7	6,5	4	1	3,37	1,00	24,86	204,81	0,00	0	-0,88
59		output machine 2	2,50	9,75	14,00	-13,00	7	6,5	1	4	3,37	1,00	24,86	649,81	0,00	0	-0,96
60		palette parking 1	2,50	9,75	12,14	5,95	7	6,5	1	1	3,37	0,50	19,50	107,29	0,00	0	-0,82
61		palette parking 2	2,50	9,75	16,86	-10,65	7	6,5	1	1	3,37	0,50	19,50	622,54	0,00	0	-0,97
62		missprint warehouse	2,50	9,75	15,00	13,00	7	6,5	8	8	3,37	4,00	70,66	166,81	0,00	0	-0,58
63		product storage	2,50	9,75	-15,74	13,74	7	6,5	17	2,5	3,37	3,26	57,18	348,64	0,00	0	-0,84
64		north gate	2,50	9,75	18,65	-14,50	7	6,5	0,1	5	3,37	0,35	18,05	848,72	0,00	0	-0,98
65		east gate	2,50	9,75	-17,00	-16,69	7	6,5	4	0,1	3,37	0,32	17,69	1079,06	0,00	0	-0,98
66	machine 1/input machine 1	machine 2	14,00	-0,50	6,00	-13,00	4	10	15	4	3,16	3,87	64,34	220,25	0,00	0	-0,71
67		input machine 2	14,00	-0,50	-5,00	-13,00	4	10	7	4	3,16	2,65	43,85	517,25	0,00	0	-0,92
68		output machine 1	14,00	-0,50	16,00	5,00	4	10	4	1	3,16	1,00	22,52	34,25	0,00	0	-0,34
69		output machine 2	14,00	-0,50	14,00	-13,00	4	10	1	4	3,16	1,00	22,52	156,25	0,00	0	-0,86
70		palette parking 1	14,00	-0,50	12,14	5,95	4	10	1	1	3,16	0,50	17,44	45,06	0,00	0	-0,61
71		palette parking 2	14,00	-0,50	16,86	-10,65	4	10	1	1	3,16	0,50	17,44	111,26	0,00	0	-0,84
72		missprint warehouse	14,00	-0,50	15,00	13,00	4	10	8	8	3,16	4,00	66,69	183,25	0,00	0	-0,64
73		product storage	14,00	-0,50	-15,74	13,74	4	10	17	2,5	3,16	3,26	53,61	1087,28	0,00	0	-0,95
74		north gate	14,00	-0,50	18,65	-14,50	4	10	0,1	5	3,16	0,35	16,07	217,58	0,00	0	-0,93
75		east gate	14,00	-0,50	-17,00	-16,69	4	10	4	0,1	3,16	0,32	15,73	1222,95	0,00	0	-0,99
76	machine 2	input machine 2	6,00	-13,00	-5,00	-13,00	15	4	7	4	3,87	2,65	55,24	121,00	0,00	0	-0,54
77		output machine 1	6,00	-13,00	16,00	5,00	15	4	4	1	3,87	1,00	30,87	424,00	0,00	0	-0,93
78		output machine 2	6,00	-13,00	14,00	-13,00	15	4	1	4	3,87	1,00	30,87	64,00	0,00	0	-0,52
79		palette parking 1	6,00	-13,00	12,14	5,95	15	4	1	1							

no	α-	1	in euclidean				dimension				modules radi	target dist	distance(Dij)	cost(cij)	Dij x cij	repeller function(f)	
			from		to		from		to								
			x-axis	y-axis	x-axis	y-axis	length	width	length	width							
1	ink warehouse	CD paper warehouse	-5,50	4,50	-14,51	-3,01	5	4	11,5	7	2,24	4,49	45,19	137,68	0,00	0	-0,67
2		HVS paper warehouse	-5,50	4,50	-12,57	-13,50	5	4	7	7	2,24	3,50	32,90	373,95	0,00	0	-0,91
3		leftover paper warehouse	-5,50	4,50	2,25	-2,58	5	4	4	7	2,24	2,65	23,83	110,24	0,00	0	-0,78
4		pre-print	-5,50	4,50	2,50	9,75	5	4	7	6,5	2,24	3,37	31,46	91,56	0	0	-0,66
5		machine 1/input machine 1	-5,50	4,50	14,00	-0,50	5	4	4	10	2,24	3,16	29,14	405,25	920,00	551140	-0,93
6		machine 2	-5,50	4,50	6,00	-13,00	5	4	15	4	2,24	3,87	37,32	438,50	1360,00	403420	-0,91
7		input machine 2	-5,50	4,50	-5,00	-13,00	5	4	7	4	2,24	2,65	23,83	306,50	0,00	0	-0,92
8		output machine 1	-5,50	4,50	16,00	5,00	5	4	4	1	2,24	1,00	10,47	462,50	0,00	0	-0,98
9		output machine 2	-5,50	4,50	14,00	-13,00	5	4	1	4	2,24	1,00	10,47	686,50	0,00	0	-0,98
10		palette parking 1	-5,50	4,50	12,44	5,93	5	4	1	1	2,24	0,50	7,49	323,73	0,00	0	-0,98
11		palette parking 2	-5,50	4,50	16,40	-10,55	5	4	1	1	2,24	0,50	7,49	706,15	0,00	0	-0,99
12		missprint warehouse	-5,50	4,50	15,00	13,00	5	4	8	8	2,24	4,00	38,89	492,50	0,00	0	-0,92
13		product storage	-5,50	4,50	-15,74	12,01	5	4	17	2,5	2,24	3,26	30,20	161,26	0,00	0	-0,81
14		north gate	-5,50	4,50	18,65	-14,50	5	4	0,1	5	2,24	0,35	6,71	943,98	0,00	0	-0,99
15		east gate	-5,50	4,50	-17,00	-16,69	5	4	4	0,1	2,24	0,32	6,51	581,05	0,00	0	-0,99
16	CD paper warehouse	HVS paper warehouse	-14,51	-3,01	-12,57	-13,50	11,5	11,5	7	7	5,75	3,50	85,56	113,79	0,00	0	-0,25
17		leftover paper warehouse	-14,51	-3,01	2,25	-2,58	11,5	11,5	4	7	5,75	2,65	70,49	281,34	0,00	0	-0,75
18		pre-print	-14,51	-3,01	2,50	9,75	11,5	11,5	7	6,5	5,75	3,37	83,22	452,34	0,00	0	-0,82
19		machine 1/input machine 1	-14,51	-3,01	14,00	-0,50	11,5	11,5	4	10	5,75	3,16	79,43	819,35	2160,00	1769801,945	-0,90
20		machine 2	-14,51	-3,01	6,00	-13,00	11,5	11,5	15	4	5,75	3,87	92,60	520,58	0,00	0	-0,82
21		input machine 2	-14,51	-3,01	-5,00	-13,00	11,5	11,5	7	4	5,75	2,65	70,49	190,28	5040,00	958993,7253	-0,63
22		output machine 1	-14,51	-3,01	16,00	5,00	11,5	11,5	4	1	5,75	1,00	45,56	995,29	0,00	0	-0,95
23		output machine 2	-14,51	-3,01	14,00	-13,00	11,5	11,5	1	4	5,75	1,00	45,56	912,81	0,00	0	-0,95
24		palette parking 1	-14,51	-3,01	12,44	5,93	11,5	11,5	1	1	5,75	0,50	39,06	806,24	0,00	0	-0,95
25		palette parking 2	-14,51	-3,01	16,40	-10,55	11,5	11,5	1	1	5,75	0,50	39,06	1012,61	0,00	0	-0,96
26		missprint warehouse	-14,51	-3,01	15,00	13,00	11,5	11,5	8	8	5,75	4,00	95,06	1127,45	0,00	0	-0,92
27		product storage	-14,51	-3,01	-15,74	12,01	11,5	11,5	17	2,5	5,75	3,26	81,17	227,16	0,00	0	-0,64
28		north gate	-14,51	-3,01	18,65	-14,50	11,5	11,5	0,1	5	5,75	0,35	37,25	1231,49	0,00	0	-0,97
29		east gate	-14,51	-3,01	-17,00	-16,69	11,5	11,5	4	0,1	5,75	0,32	36,80	193,13	7200,00	1390566,015	-0,81
30	HVS paper warehouse	leftover paper warehouse	-12,57	-13,50	2,25	-2,58	7	7	4	7	3,50	2,65	37,77	338,92	0,00	0	-0,89
31		pre-print	-12,57	-13,50	2,50	9,75	7	7	7	6,5	3,50	3,37	47,23	767,58	0,00	0	-0,94
32		machine 1/input machine 1	-12,57	-13,50	14,00	-0,50	7	7	4	10	3,50	3,16	44,39	874,82	2190,00	1915848,376	-0,95
33		machine 2	-12,57	-13,50	6,00	-13,00	7	7	15	4	3,50	3,87	54,36	344,99	0,00	0	-0,84
34		input machine 2	-12,57	-13,50	-5,00	-13,00	7	7	7	4	3,50	2,65	37,77	57,51	2190,00	125952,7179	-0,34
35		output machine 1	-12,57	-13,50	16,00	5,00	7	7	4	1	3,50	1,00	20,25	1158,34	0,00	0	-0,98
36		output machine 2	-12,57	-13,50	14,00	-13,00	7	7	1	4	3,50	1,00	20,25	706,07	0,00	0	-0,97
37		palette parking 1	-12,57	-13,50	12,44	5,93	7	7	1	1	3,50	0,50	16,00	1002,70	0,00	0	-0,98
38		palette parking 2	-12,57	-13,50	16,40	-10,55	7	7	1	1	3,50	0,50	16,00	847,96	0,00	0	-0,98
39		missprint warehouse	-12,57	-13,50	15,00	13,00	7	7	8	8	3,50	4,00	56,25	1462,20	0,00	0	-0,96
40		product storage	-12,57	-13,50	-15,74	12,01	7	7	17	2,5	3,50	3,26	45,69	660,82	0,00	0	-0,93
41		north gate	-12,57	-13,50	18,65	-14,50	7	7	0,1	5	3,50	0,35	14,85	975,20	0,00	0	-0,98
42		east gate	-12,57	-13,50	-17,00	-16,69	7	7	4	0,1	3,50	0,32	14,56	29,79	4380,00	130497,0998	-0,51
43	leftover paper warehouse	pre-print	2,25	-2,58	2,50	9,75	4	7	7	6,5	2,65	3,37	36,22	152,08	0,00	0	-0,76
44		machine 1/input machine 1	2,25	-2,58	14,00	-0,50	4	7	4	10	2,65	3,16	33,73	142,30	390,00	55496,82448	-0,76
45		machine 2	2,25	-2,58	6,00	-13,00	4	7	15	4	2,65	3,87	42,49	122,62	0,00	0	-0,65
46		input machine 2	2,25	-2,58	-5,00	-13,00	4	7	7	4	2,65	2,65	28,00	161,20	580,00	93498,48467	-0,83
47		output machine 1	2,25	-2,58	16,00	5,00	4	7	4	1	2,65	1,00	13,29	246,41	0,00	0	-0,95
48		output machine 2	2,25	-2,58	14,00	-13,00	4	7	1	4	2,65	1,00	13,29	246,56	0,00	0	-0,95
49		palette parking 1	2,25	-2,58	12,44	5,93	4	7	1	1	2,65	0,50	9,90	176,10	0,00	0	-0,94
50		palette parking 2	2,25	-2,58	16,40	-10,55	4	7	1	1	2,65	0,50	9,90	263,68	0,00	0	-0,96
51		missprint warehouse	2,25	-2,58	15,00	13,00	4	7	8	8	2,65	4,00	44,17	405,19	0,00	0	-0,89
52		product storage	2,25	-2,58	-15,74	12,01	4	7	17	2,5	2,65	3,26	34,87	536,64	0,00	0	-0,94
53		north gate	2,25	-2,58	18,65	-14,50	4	7	0,1	5	2,65	0,35	9,00	410,77	0,00	0	-0,98
54		east gate	2,25	-2,58	-17,00	-16,69	4	7	4	0,1	2,65	0,32	8,77	569,67	0,00	0	-0,98
55	pre-print	machine 1/input machine 1	2,50	9,75	14,00	-0,50	7	6,5	4	10	3,37	3,16	42,71	237,31	5620,00	1333696,25	-0,82
56		machine 2	2,50	9,75	6,00	-13,00	7	6,5	15	4	3,37	3,87	52,50	529,81	8430,00	4466319,375	-0,90
57		input machine 2	2,50	9,75	-5,00	-13,00	7	6,5	7	4	3,37	2,65	36,22	573,81	0,00	0	-0,94
58		output machine 1	2,50	9,75	16,00	5,00	7	6,5	4	1	3,37	1,00	19,12	204,81	0,00	0	-0,91
59		output machine 2	2,50	9,75	14,00	-13,00	7	6,5	1	4	3,37	1,00	19,12	649,81	0,00	0	-0,97
60		palette parking 1	2,50	9,75	12,44	5,93	7	6,5	1	1	3,37	0,50	15,00	113,30	0,00	0	-0,87
61		palette parking 2	2,50	9,75	16,40	-10,55	7	6,5	1	1	3,37	0,50	15,00	605,28	0,00	0	-0,98
62		missprint warehouse	2,50	9,75	15,00	13,00	7	6,5	8	8	3,37	4,00	54,36	166,81	0,00	0	-0,67
63		product storage	2,50	9,75	-15,74	12,01	7	6,5	17	2,5	3,37	3,26	43,99	337,82	0,00	0	-0,87
64		north gate	2,50	9,75	18,65	-14,50	7	6,5	0,1	5	3,37	0,35	13,88	848,72	0,00	0	-0,98
65		east gate	2,50	9,75	-17,00	-16,69	7	6,5	4	0,1	3,37	0,32	13,61	1079,06	0,00	0	-0,99
66	machine 1/input machine 1	machine 2	14,00	-0,50	6,00	-13,00	4	10	15	4	3,16	3,87	49,49	220,25	0,00	0	-0,78
67		input machine 2	14,00	-0,50	-5,00	-13,00	4	10	7	4	3,16	2,65	33,73	517,25	0,00	0	-0,93
68		output machine 1	14,00	-0,50	16,00	5,00	4	10	4	1	3,16	1,00	17,32	34,25	0,00	0	-0,49
69		output machine 2	14,00	-0,50	14,00	-13,00	4	10	1	4	3,16	1,00	17,32	156,25	0,00	0	-0,89
70		palette parking 1	14,00	-0,50	12,44	5,93	4	10	1	1	3,16	0,50	13,41	43,81	0,00	0	-0,69
71		palette parking 2	14,00	-0,50	16,40	-10,55	4	10	1	1	3,16	0,50	13,41	106,73	0,00	0	-0,87
72		missprint warehouse	14,00	-0,50	15,00	13,00	4	10	8	8	3,16	4,00	51,30	183,25	0,00	0	-0,72
73		product storage	14,00	-0,50	-15,74	12,01	4	10	17	2,5	3,16	3,26	41,24	1040,99	0,00	0	-0,96
74		north gate	14,00	-0,50	18,65	-14,50	4	10	0,1	5	3,16	0,35	12,36	217,58	0,00	0	-0,94
75		east gate	14,00	-0,50	-17,00	-16,69	4	10	4	0,1	3,16	0,32	12,10	1222,95	0,00	0	-0,99
76	machine 2	input machine 2	6,00	-13,00	-5,00	-13,00	15	4	7	4	3,87	2,65	42,49	121,00	0,00	0	-0,65
77		output machine 1	6,00	-13,00	16,00	5,00	15	4	4	1	3,87	1,00	23,75	424,00	0,00	0	-0,94
78		output machine 2	6,00	-13,00	14,00	-13,00	15	4	1	4	3,87	1,00	23,75	64,00	0,00	0	-0,63
79		palette parking 1	6,00	-13,00	12,44	5,93	15	4	1	1	3,87						

no	α-	to	in euclidean				dimension				modules radi	target dist	distance(Dij)	cost(cij)	Dij x cij	repeller function(f)	
			from		to		from		to								
			x-axis	y-axis	x-axis	y-axis	length	width	length	width							
1	ink warehouse	CD paper warehouse	-5,50	4,50	-12,03	-6,99	5	4	11,5	7	2,24	4,49	4,52	174,55	0,00	0	-0,97
2		HVS paper warehouse	-5,50	4,50	-10,68	-13,50	5	4	7	7	2,24	3,50	3,29	350,79	0,00	0	-0,99
3		leftover paper warehouse	-5,50	4,50	4,36	-0,25	5	4	4	7	2,24	2,65	2,38	119,68	0,00	0	-0,98
4		pre-print	-5,50	4,50	2,50	9,75	5	4	7	6,5	2,24	3,37	3,15	91,56	0	0	-0,97
5		machine 1/input machine 1	-5,50	4,50	14,00	-0,50	5	4	4	10	2,24	3,16	2,91	405,25	920,00	551140	-0,99
6		machine 2	-5,50	4,50	6,00	-13,00	5	4	15	4	2,24	3,87	3,73	438,50	1360,00	403420	-0,99
7		input machine 2	-5,50	4,50	-5,00	-13,00	5	4	7	4	2,24	2,65	2,38	306,50	0,00	0	-0,99
8		output machine 1	-5,50	4,50	16,00	5,00	5	4	4	1	2,24	1,00	1,05	462,50	0,00	0	-1,00
9		output machine 2	-5,50	4,50	14,00	-13,00	5	4	1	4	2,24	1,00	1,05	686,50	0,00	0	-1,00
10		palette parking 1	-5,50	4,50	14,28	4,01	5	4	1	1	2,24	0,50	0,75	391,66	0,00	0	-1,00
11		palette parking 2	-5,50	4,50	13,05	-11,35	5	4	1	1	2,24	0,50	0,75	595,51	0,00	0	-1,00
12		missprint warehouse	-5,50	4,50	15,00	9,35	5	4	8	8	2,24	4,00	3,89	443,73	0,00	0	-0,99
13		product storage	-5,50	4,50	-0,59	-7,13	5	4	17	2,5	2,24	3,26	3,02	159,51	0,00	0	-0,98
14		north gate	-5,50	4,50	18,65	-14,50	5	4	0,1	5	2,24	0,35	0,67	943,98	0,00	0	-1,00
15		east gate	-5,50	4,50	-17,00	-16,69	5	4	4	0,1	2,24	0,32	0,65	581,05	0,00	0	-1,00
16	CD paper warehouse	HVS paper warehouse	-12,03	-6,99	-10,68	-13,50	11,5	11,5	7	7	5,75	3,50	8,56	44,27	0,00	0	-0,81
17		leftover paper warehouse	-12,03	-6,99	4,36	-0,25	11,5	11,5	4	7	5,75	2,65	7,05	313,83	0,00	0	-0,98
18		pre-print	-12,03	-6,99	2,50	9,75	11,5	11,5	7	6,5	5,75	3,37	8,32	491,17	0,00	0	-0,98
19		machine 1/input machine 1	-12,03	-6,99	14,00	-0,50	11,5	11,5	4	10	5,75	3,16	7,94	719,57	2160,00	1554280,535	-0,99
20		machine 2	-12,03	-6,99	6,00	-13,00	11,5	11,5	15	4	5,75	3,87	9,26	361,22	0,00	0	-0,97
21		input machine 2	-12,03	-6,99	-5,00	-13,00	11,5	11,5	7	4	5,75	2,65	7,05	85,58	5040,00	431330,3717	-0,92
22		output machine 1	-12,03	-6,99	16,00	5,00	11,5	11,5	4	1	5,75	1,00	4,56	929,28	0,00	0	-1,00
23		output machine 2	-12,03	-6,99	14,00	-13,00	11,5	11,5	1	4	5,75	1,00	4,56	713,69	0,00	0	-0,99
24		palette parking 1	-12,03	-6,99	14,28	4,01	11,5	11,5	1	1	5,75	0,50	3,91	813,28	0,00	0	-1,00
25		palette parking 2	-12,03	-6,99	13,05	-11,35	11,5	11,5	1	1	5,75	0,50	3,91	648,22	0,00	0	-0,99
26		missprint warehouse	-12,03	-6,99	15,00	9,35	11,5	11,5	8	8	5,75	4,00	9,51	997,27	0,00	0	-0,99
27		product storage	-12,03	-6,99	-0,59	-7,13	11,5	11,5	17	2,5	5,75	3,26	8,12	130,96	0,00	0	-0,94
28		north gate	-12,03	-6,99	18,65	-14,50	11,5	11,5	0,1	5	5,75	0,35	3,73	997,37	0,00	0	-1,00
29		east gate	-12,03	-6,99	-17,00	-16,69	11,5	11,5	4	0,1	5,75	0,32	3,68	118,79	7200,00	855285,9605	-0,97
30	HVS paper warehouse	leftover paper warehouse	-10,68	-13,50	4,36	-0,25	7	7	4	7	3,50	2,65	3,78	401,54	0,00	0	-0,99
31		pre-print	-10,68	-13,50	2,50	9,75	7	7	7	6,5	3,50	3,37	4,72	714,18	0,00	0	-0,99
32		machine 1/input machine 1	-10,68	-13,50	14,00	-0,50	7	7	4	10	3,50	3,16	4,44	777,92	2190,00	1703640,101	-0,99
33		machine 2	-10,68	-13,50	6,00	-13,00	7	7	15	4	3,50	3,87	5,44	278,35	0,00	0	-0,98
34		input machine 2	-10,68	-13,50	-5,00	-13,00	7	7	7	4	3,50	2,65	3,78	32,47	2190,00	71109,16495	-0,88
35		output machine 1	-10,68	-13,50	16,00	5,00	7	7	4	1	3,50	1,00	2,03	1053,87	0,00	0	-1,00
36		output machine 2	-10,68	-13,50	14,00	-13,00	7	7	1	4	3,50	1,00	2,03	609,17	0,00	0	-1,00
37		palette parking 1	-10,68	-13,50	14,28	4,01	7	7	1	1	3,50	0,50	1,60	929,60	0,00	0	-1,00
38		palette parking 2	-10,68	-13,50	13,05	-11,35	7	7	1	1	3,50	0,50	1,60	567,74	0,00	0	-1,00
39		missprint warehouse	-10,68	-13,50	15,00	9,35	7	7	8	8	3,50	4,00	5,63	1181,18	0,00	0	-1,00
40		product storage	-10,68	-13,50	-0,59	-7,13	7	7	17	2,5	3,50	3,26	4,57	142,32	0,00	0	-0,97
41		north gate	-10,68	-13,50	18,65	-14,50	7	7	0,1	5	3,50	0,35	1,48	860,74	0,00	0	-1,00
42		east gate	-10,68	-13,50	-17,00	-16,69	7	7	4	0,1	3,50	0,32	1,46	50,13	4380,00	219586,4847	-0,97
43	leftover paper warehouse	pre-print	4,36	-0,25	2,50	9,75	4	7	7	6,5	2,65	3,37	3,62	103,42	0,00	0	-0,96
44		machine 1/input machine 1	4,36	-0,25	14,00	-0,50	4	7	4	10	2,65	3,16	3,37	93,08	390,00	36301,25293	-0,96
45		machine 2	4,36	-0,25	6,00	-13,00	4	7	15	4	2,65	3,87	4,25	165,29	0,00	0	-0,97
46		input machine 2	4,36	-0,25	-5,00	-13,00	4	7	7	4	2,65	2,65	2,80	250,12	580,00	145066,7099	-0,99
47		output machine 1	4,36	-0,25	16,00	5,00	4	7	4	1	2,65	1,00	1,33	163,15	0,00	0	-0,99
48		output machine 2	4,36	-0,25	14,00	-13,00	4	7	1	4	2,65	1,00	1,33	255,61	0,00	0	-0,99
49		palette parking 1	4,36	-0,25	14,28	4,01	4	7	1	1	2,65	0,50	0,99	116,71	0,00	0	-0,99
50		palette parking 2	4,36	-0,25	13,05	-11,35	4	7	1	1	2,65	0,50	0,99	198,93	0,00	0	-1,00
51		missprint warehouse	4,36	-0,25	15,00	9,35	4	7	8	8	2,65	4,00	4,42	205,36	0,00	0	-0,98
52		product storage	4,36	-0,25	-0,59	-7,13	4	7	17	2,5	2,65	3,26	3,49	71,83	0,00	0	-0,95
53		north gate	4,36	-0,25	18,65	-14,50	4	7	0,1	5	2,65	0,35	0,90	407,28	0,00	0	-1,00
54		east gate	4,36	-0,25	-17,00	-16,69	4	7	4	0,1	2,65	0,32	0,88	726,20	0,00	0	-1,00
55	pre-print	machine 1/input machine 1	2,50	9,75	14,00	-0,50	7	6,5	4	10	3,37	3,16	4,27	237,31	5620,00	1333696,25	-0,98
56		machine 2	2,50	9,75	6,00	-13,00	7	6,5	15	4	3,37	3,87	5,25	529,81	8430,00	4466319,375	-0,99
57		input machine 2	2,50	9,75	-5,00	-13,00	7	6,5	7	4	3,37	2,65	3,62	573,81	0,00	0	-0,99
58		output machine 1	2,50	9,75	16,00	5,00	7	6,5	4	1	3,37	1,00	1,91	204,81	0,00	0	-0,99
59		output machine 2	2,50	9,75	14,00	-13,00	7	6,5	1	4	3,37	1,00	1,91	649,81	0,00	0	-1,00
60		palette parking 1	2,50	9,75	14,28	4,01	7	6,5	1	1	3,37	0,50	1,50	171,83	0,00	0	-0,99
61		palette parking 2	2,50	9,75	13,05	-11,35	7	6,5	1	1	3,37	0,50	1,50	556,65	0,00	0	-1,00
62		missprint warehouse	2,50	9,75	15,00	9,35	7	6,5	8	8	3,37	4,00	5,44	156,41	0,00	0	-0,97
63		product storage	2,50	9,75	-0,59	-7,13	7	6,5	17	2,5	3,37	3,26	4,40	294,61	0,00	0	-0,99
64		north gate	2,50	9,75	18,65	-14,50	7	6,5	0,1	5	3,37	0,35	1,39	848,72	0,00	0	-1,00
65		east gate	2,50	9,75	-17,00	-16,69	7	6,5	4	0,1	3,37	0,32	1,36	1079,06	0,00	0	-1,00
66	machine 1/input machine 1	machine 2	14,00	-0,50	6,00	-13,00	4	10	15	4	3,16	3,87	4,95	220,25	0,00	0	-0,98
67		input machine 2	14,00	-0,50	-5,00	-13,00	4	10	7	4	3,16	2,65	3,37	517,25	0,00	0	-0,99
68		output machine 1	14,00	-0,50	16,00	5,00	4	10	4	1	3,16	1,00	1,73	34,25	0,00	0	-0,95
69		output machine 2	14,00	-0,50	14,00	-13,00	4	10	1	4	3,16	1,00	1,73	156,25	0,00	0	-0,99
70		palette parking 1	14,00	-0,50	14,28	4,01	4	10	1	1	3,16	0,50	1,34	20,41	0,00	0	-0,93

no	from	to	in euclidean				dimension				modules radi		target dist	distance(Dij)	cost(cij)	Dij x cij	repeller function(f)
			from		to		from		to		from	to					
			x-axis	y-axis	x-axis	y-axis	length	width	length	width	from	to					
1	ink warehouse	CD paper warehouse	-5,50	4,50	-10,14	-12,51	5	4	11,5	7	2,24	4,49	0,45	311,02	0,00	0	-1,00
2		HVS paper warehouse	-5,50	4,50	-6,28	-9,01	5	4	7	7	2,24	3,50	0,33	183,23	0,00	0	-1,00
3		leftover paper warehouse	-5,50	4,50	2,97	-4,57	5	4	4	7	2,24	2,65	0,24	153,93	0,00	0	-1,00
4		pre-print	-5,50	4,50	2,50	9,75	5	4	7	6,5	2,24	3,37	0,31	91,56	0	0	-1,00
5		machine 1/input machine 1	-5,50	4,50	14,00	-0,50	5	4	4	10	2,24	3,16	0,29	405,25	920,00	551140	-1,00
6		machine 2	-5,50	4,50	6,00	-13,00	5	4	15	4	2,24	3,87	0,37	438,50	1360,00	403420	-1,00
7		input machine 2	-5,50	4,50	-5,00	-13,00	5	4	7	4	2,24	2,65	0,24	306,50	0,00	0	-1,00
8		output machine 1	-5,50	4,50	16,00	5,00	5	4	4	1	2,24	1,00	0,10	462,50	0,00	0	-1,00
9		output machine 2	-5,50	4,50	14,00	-13,00	5	4	1	4	2,24	1,00	0,10	686,50	0,00	0	-1,00
10		palette parking 1	-5,50	4,50	14,84	4,99	5	4	1	1	2,24	0,50	0,07	414,01	0,00	0	-1,00
11		palette parking 2	-5,50	4,50	13,02	-13,25	5	4	1	1	2,24	0,50	0,07	657,86	0,00	0	-1,00
12		missprint warehouse	-5,50	4,50	10,84	1,11	5	4	8	8	2,24	4,00	0,39	278,47	0,00	0	-1,00
13		product storage	-5,50	4,50	-0,19	-10,11	5	4	17	2,5	2,24	3,26	0,30	241,49	0,00	0	-1,00
14		north gate	-5,50	4,50	18,65	-14,50	5	4	0,1	5	2,24	0,35	0,07	943,98	0,00	0	-1,00
15		east gate	-5,50	4,50	-17,00	-16,69	5	4	4	0,1	2,24	0,32	0,07	581,05	0,00	0	-1,00
16	CD paper warehouse	HVS paper warehouse	-10,14	-12,51	-6,28	-9,01	11,5	11,5	7	7	5,75	3,50	0,86	27,15	0,00	0	-0,97
17		leftover paper warehouse	-10,14	-12,51	2,97	-4,57	11,5	11,5	4	7	5,75	2,65	0,70	235,13	0,00	0	-1,00
18		pre-print	-10,14	-12,51	2,50	9,75	11,5	11,5	7	6,5	5,75	3,37	0,83	655,50	0,00	0	-1,00
19		machine 1/input machine 1	-10,14	-12,51	14,00	-0,50	11,5	11,5	4	10	5,75	3,16	0,79	727,16	2160,00	1570659,789	-1,00
20		machine 2	-10,14	-12,51	6,00	-13,00	11,5	11,5	15	4	5,75	3,87	0,93	260,79	0,00	0	-1,00
21		input machine 2	-10,14	-12,51	-5,00	-13,00	11,5	11,5	7	4	5,75	2,65	0,70	26,67	5040,00	134435,4491	-0,97
22		output machine 1	-10,14	-12,51	16,00	5,00	11,5	11,5	4	1	5,75	1,00	0,46	990,13	0,00	0	-1,00
23		output machine 2	-10,14	-12,51	14,00	-13,00	11,5	11,5	1	4	5,75	1,00	0,46	583,06	0,00	0	-1,00
24		palette parking 1	-10,14	-12,51	14,84	4,99	11,5	11,5	1	1	5,75	0,50	0,39	930,62	0,00	0	-1,00
25		palette parking 2	-10,14	-12,51	13,02	-13,25	11,5	11,5	1	1	5,75	0,50	0,39	536,92	0,00	0	-1,00
26		missprint warehouse	-10,14	-12,51	10,84	1,11	11,5	11,5	8	8	5,75	4,00	0,95	625,72	0,00	0	-1,00
27		product storage	-10,14	-12,51	-0,19	-10,11	11,5	11,5	17	2,5	5,75	3,26	0,81	104,75	0,00	0	-0,99
28		north gate	-10,14	-12,51	18,65	-14,50	11,5	11,5	0,1	5	5,75	0,35	0,37	832,62	0,00	0	-1,00
29		east gate	-10,14	-12,51	-17,00	-16,69	11,5	11,5	4	0,1	5,75	0,32	0,37	64,43	7200,00	463923,4773	-0,99
30	HVS paper warehouse	leftover paper warehouse	-6,28	-9,01	2,97	-4,57	7	7	4	7	3,50	2,65	0,38	105,41	0,00	0	-1,00
31		pre-print	-6,28	-9,01	2,50	9,75	7	7	7	6,5	3,50	3,37	0,47	429,21	0,00	0	-1,00
32		machine 1/input machine 1	-6,28	-9,01	14,00	-0,50	7	7	4	10	3,50	3,16	0,44	483,86	2190,00	1059650,699	-1,00
33		machine 2	-6,28	-9,01	6,00	-13,00	7	7	15	4	3,50	3,87	0,54	166,75	0,00	0	-1,00
34		input machine 2	-6,28	-9,01	-5,00	-13,00	7	7	7	4	3,50	2,65	0,38	17,53	2190,00	38400,56599	-0,98
35		output machine 1	-6,28	-9,01	16,00	5,00	7	7	4	1	3,50	1,00	0,20	692,89	0,00	0	-1,00
36		output machine 2	-6,28	-9,01	14,00	-13,00	7	7	1	4	3,50	1,00	0,20	427,26	0,00	0	-1,00
37		palette parking 1	-6,28	-9,01	14,84	4,99	7	7	1	1	3,50	0,50	0,16	642,38	0,00	0	-1,00
38		palette parking 2	-6,28	-9,01	13,02	-13,25	7	7	1	1	3,50	0,50	0,16	390,43	0,00	0	-1,00
39		missprint warehouse	-6,28	-9,01	10,84	1,11	7	7	8	8	3,50	4,00	0,56	395,57	0,00	0	-1,00
40		product storage	-6,28	-9,01	-0,19	-10,11	7	7	17	2,5	3,50	3,26	0,46	38,26	0,00	0	-0,99
41		north gate	-6,28	-9,01	18,65	-14,50	7	7	0,1	5	3,50	0,35	0,15	651,47	0,00	0	-1,00
42		east gate	-6,28	-9,01	-17,00	-16,69	7	7	4	0,1	3,50	0,32	0,15	173,72	4380,00	760873,4111	-1,00
43	leftover paper warehouse	pre-print	2,97	-4,57	2,50	9,75	4	7	7	6,5	2,65	3,37	0,36	205,14	0,00	0	-1,00
44		machine 1/input machine 1	2,97	-4,57	14,00	-0,50	4	7	4	10	2,65	3,16	0,34	138,17	390,00	53884,6531	-1,00
45		machine 2	2,97	-4,57	6,00	-13,00	4	7	15	4	2,65	3,87	0,42	80,32	0,00	0	-0,99
46		input machine 2	2,97	-4,57	-5,00	-13,00	4	7	7	4	2,65	2,65	0,28	134,68	580,00	78116,23101	-1,00
47		output machine 1	2,97	-4,57	16,00	5,00	4	7	4	1	2,65	1,00	0,13	261,25	0,00	0	-1,00
48		output machine 2	2,97	-4,57	14,00	-13,00	4	7	1	4	2,65	1,00	0,13	192,79	0,00	0	-1,00
49		palette parking 1	2,97	-4,57	14,84	4,99	4	7	1	1	2,65	0,50	0,10	232,25	0,00	0	-1,00
50		palette parking 2	2,97	-4,57	13,02	-13,25	4	7	1	1	2,65	0,50	0,10	176,32	0,00	0	-1,00
51		missprint warehouse	2,97	-4,57	10,84	1,11	4	7	8	8	2,65	4,00	0,44	94,08	0,00	0	-1,00
52		product storage	2,97	-4,57	-0,19	-10,11	4	7	17	2,5	2,65	3,26	0,35	40,72	0,00	0	-0,99
53		north gate	2,97	-4,57	18,65	-14,50	4	7	0,1	5	2,65	0,35	0,09	344,38	0,00	0	-1,00
54		east gate	2,97	-4,57	-17,00	-16,69	4	7	4	0,1	2,65	0,32	0,09	545,73	0,00	0	-1,00
55	pre-print	machine 1/input machine 1	2,50	9,75	14,00	-0,50	7	6,5	4	10	3,37	3,16	0,43	237,31	5620,00	1333696,25	-1,00
56		machine 2	2,50	9,75	6,00	-13,00	7	6,5	15	4	3,37	3,87	0,52	529,81	8430,00	4466319,375	-1,00
57		input machine 2	2,50	9,75	-5,00	-13,00	7	6,5	7	4	3,37	2,65	0,36	573,81	0,00	0	-1,00
58		output machine 1	2,50	9,75	16,00	5,00	7	6,5	4	1	3,37	1,00	0,19	204,81	0,00	0	-1,00
59		output machine 2	2,50	9,75	14,00	-13,00	7	6,5	1	4	3,37	1,00	0,19	649,81	0,00	0	-1,00
60		palette parking 1	2,50	9,75	14,84	4,99	7	6,5	1	1	3,37	0,50	0,15	174,95	0,00	0	-1,00
61		palette parking 2	2,50	9,75	13,02	-13,25	7	6,5	1	1	3,37	0,50	0,15	639,47	0,00	0	-1,00
62		missprint warehouse	2,50	9,75	10,84	1,11	7	6,5	8	8	3,37	4,00	0,54	144,23	0,00	0	-1,00
63		product storage	2,50	9,75	-0,19	-10,11	7	6,5	17	2,5	3,37	3,26	0,44	401,53	0,00	0	-1,00
64		north gate	2,50	9,75	18,65	-14,50	7	6,5	0,1	5	3,37	0,35	0,14	848,72	0,00	0	-1,00
65		east gate	2,50	9,75	-17,00	-16,69	7	6,5	4	0,1	3,37	0,32	0,14	1079,06	0,00	0	-1,00
66	machine 1/input machine 1	machine 2	14,00	-0,50	6,00	-13,00	4	10	15	4	3,16	3,87	0,49	220,25	0,00	0	-1,00
67		input machine 2	14,00	-0,50	-5,00	-13,00	4	10	7	4	3,16	2,65	0,34	517,25	0,00	0	-1,00
68		output machine 1	14,00	-0,50	16,00	5,00	4	10	4	1	3,16	1,00	0,17	34,25	0,00	0	-0,99
69		output machine 2	14,00	-0,50	14,00	-13,00	4	10	1	4	3,16	1,00	0,17	156,25	0,00	0	-1,00
70		palette parking 1	14,00	-0,50	14,84	4,99	4	10	1	1	3,16	0,50	0,13	30,87	0,00	0	