OPTIMAL FACILITY LOCATION:
A CASE OF GYPSUM FIBERBOARD CO., LTD.

By
ARNE SUTHAMPHONG

A Final Report of the Six-Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN SUPPLY CHAIN MANAGEMENT

Martin de Tours School of Management
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Assumption University
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Declaration of Authorship Form

I, Arne Suthamphong

declare that this thesis/project and the work presented in it are my own and has been generated by me as the result of my own original research.

Optimal facility location, a case study of Gypsum Fiberboard Co., Ltd.

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(Dr. Wuthichai Wongthatsanekorn)

Date ______________________

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Finally I would like to thank my parents for supporting and encouraging me to pursue this degree. Without them I would not have finished the degree.

Arne Suthamphong
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November 2011

ABSTRACT

The aim of this study is to help Gypsum Fiberboard to find a location for its expansion which minimizes the total transportation cost. Gypsum Fiberboard Co., Ltd is in the lime burning business. In this business transportation cost is an important factor. Lime burning factories usually locate themselves next to the raw material source to achieve low transportation cost. The current location of Gypsum Fiberboard Co., Ltd. is 22 km away from the raw material source and on average 200 km away from its customers.

Facility location models including the center of gravity method and Alfred Weber's theory have been used to discover an alternative location for the expansion of Gypsum Fiberboard Co., Ltd. Through the help of the load distance method, the best alternative location was chosen. The total transportation cost for the best alternative location has been calculated and compared to Gypsum Fiberboard's current location. The result was that the new location could save up to 5,004,000 baht/year on transportation cost. The additional cost of moving the facility to the new location has been calculated, separated into fixed and variable cost. The fixed cost equaled 15,862,000 baht, whereas the variable cost equaled 49,500 baht/month. The NPV, IRR and Payback period have been calculated. All of the results were favorable for investing in the new location, consisting of NPV = 3,257,572 (5 years, 7%), IRR = 19.84% and Payback period = 3 years 7 months. Finally, qualitative factors concerning the new location have been gathered through interviews with the manager and owner. These factors reveal another perspective of moving to the new location. Overall, the qualitative factors are in favor of the new location.

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CHAPTER I

GENERALITIES OF THE STUDY

Finding an optimal location is a key for business to succeed in today's world, as competition is facing business from all different directions. A business that does not have any competitive advantage over its competitors can be easily forced out of the market. Being located in an optimal location is one of the most sustainable strategic advantages.

Facility location is one of the most important strategic decisions in supply chain management. It requires a very high investment and it cannot be altered in the short term. For any supply chain to be effective, the location of the facilities must be in the right position. Even though all other components in the supply chain are working effectively such as inventory, production and transportation, however if the location of the facility is not at the right place, excess cost would immediately occur in that system. This is especially the case for products in the category of heavy manufacturing and weight losing (weight is lost in the production process). Following is an example how the location of a company could have a huge impact on the firm's competitive position. Example: in these days JIT, low inventory, and short lead time have become major issues for many industries, therefore if the company could locate itself near to the customer, it would have gained a critical strategic advantage.

For a company to consider moving its facility, it first has to find a good reason for it. It should ask itself: what is the problem with our present location? Once the problem has been identified, management should ask themselves whether this problem could be solved within the current location and whether a new location could solve this problem. In many situations, managers do not like to challenge themselves by making a move, because they do not want to bear the risk of the move. However this is a threat for companies in the long term, because it could cause the company to be forced out of the market.

The two main reasons why companies these days consider moving their facilities are to take advantage of labor cost and to save transportation cost.

1.1 Company Background

Gypsum Fiberboard Co., Ltd. has been established since 1996 with an authorized capital of 200,000,000 baht. The company has currently three product lines which consist of:

1. **Gypsum Fiberboards**: Gypsum Fiberboards are high quality boards used mainly for interior construction, such as interior walls and ceilings. The main market served is Taiwan and Saudi Arabia.
2. **Hard Burned Lime**: Hard Burned Lime is a special burned lime. It is used in the Autoclaved Aerated Concrete industry. The current customers served are: Super Block, Aerocrete, PCC, and Smart Concrete.
3. **Silica Powder**: Silica Powder is a raw material for the Ceramic industry. Gypsum Fiberboard Co., Ltd. is the leading supplier of this processed raw material in Thailand. Most customers are located in the central region of Thailand.

All three production sites are located in Kaengkhoi, in Saraburi province.

1.2 Background of the Study

This paper is concerned with the hard burned lime product. Hard burned lime is a special burned lime. It is used in producing Ytong bricks, and the technical name for this industry is: Autoclaved Aerated Concrete industry.

The Ytong bricks first entered into the Thai market in 1984. From then on its popularity grew tremendously. The market demand for Ytong brick has continuously been growing over the years. Especially in the next year; Mr. Yotin Uenggul, Vice President of Superblock Public Company, has forecast the demand increase for Ytong bricks to be at more than 10%. Today there are more than eight manufacturers of

Ytong bricks in Thailand. Table 1.1 shows the main Ytong manufacturers in Thailand and their approximate market share:

Table 1.1 Market Share of Ytong Manufacturers in Thailand

	Brand	Market share
1	Qcon	30 %
2	Superblock	20 %
3	Accp	5 %
4	Smart Block	5 %
5	D-con	5 %

Source: Purchasing volume of Lime in 2009.

There are two different types of process in producing Ytong bricks:

1. Cement based process.
2. Lime based process.

The lime based process requires hard burned lime in the production of bricks, whereas the cement based process requires mainly cement.

Gypsum Fiberboard Co., Ltd currently produces hard burned lime for the Ytong industry which uses the lime based process. The current customers served are: Super Block, Aerocrete, PCC, and Smart Concrete. Currently there are three producers of hard burned lime in Thailand, as listed in the Table below.

Table 1.2 Market Share of Hard Burned Lime Manufacturers in Thailand

Company	Market share
Gypsum Fiberboard Co., Ltd	35 %
United Lime Co., Ltd	35 %
Thongpol Co., Ltd	30 %

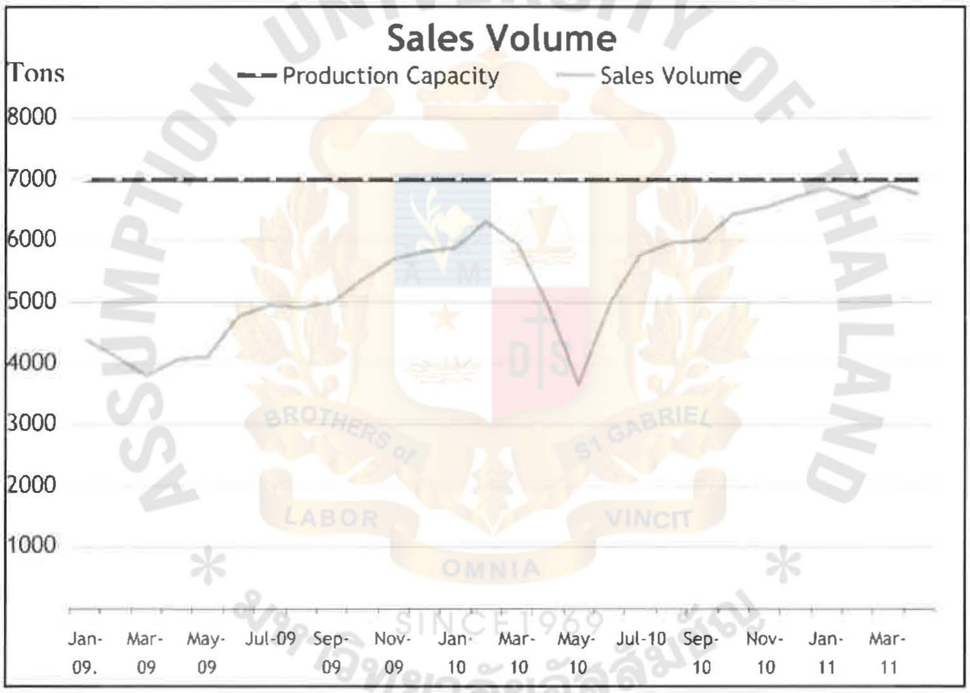
Source: The manufacturing capacity of each factory.

1.3 Statement of the Problem

Due to the increasing demand of hard burned lime, Gypsum Fiberboard Co., Ltd. has been coming to the point where it has reached its maximum production capacity.

The Table below shows Gypsum Fiberboard Co., Ltd. sales volume of hard burned lime since 2009.

Figure 1.1 Hard Burned Lime Sales Volume

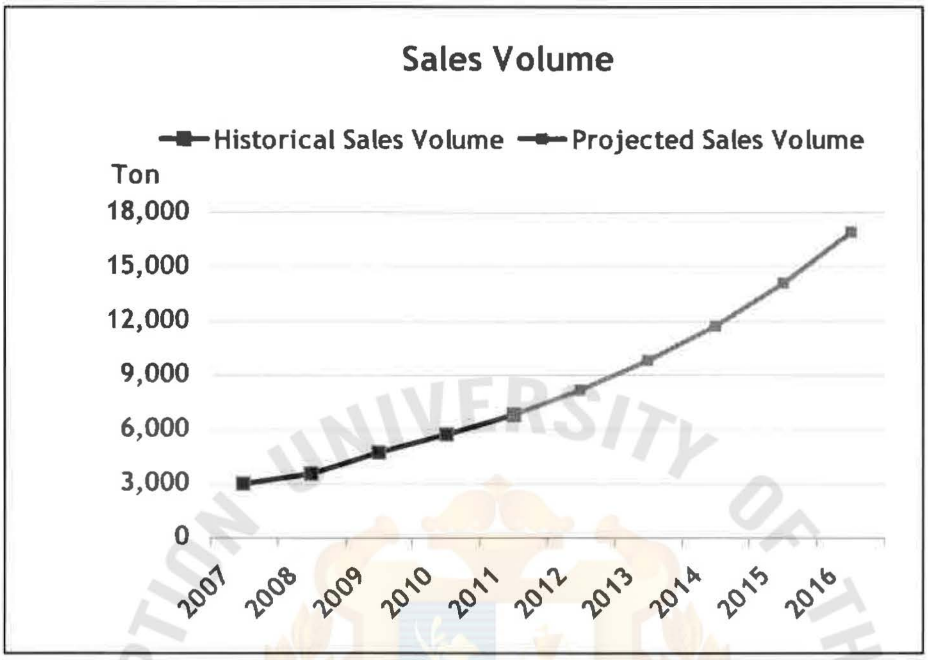


Source: Data from accounting software of Gypsum Fiberboard Co., Ltd.

The maximum production capacity of the present factory is 7,000 tons per month. The sales of the lime have been continuously rising since 2009. In March 2010 the volume dropped because of a machine break-down. Since the first quarter of 2011, the production of the hard burned lime has been at its peak capacity.

The growth rate of Gypsum Fiberboard's hard burned lime production over the past five years has been calculated. The annual growth rate was around 20% per year; this result was used as a projection for the next five years growth.

Figure 1.2 Historical and Projected Sales volume

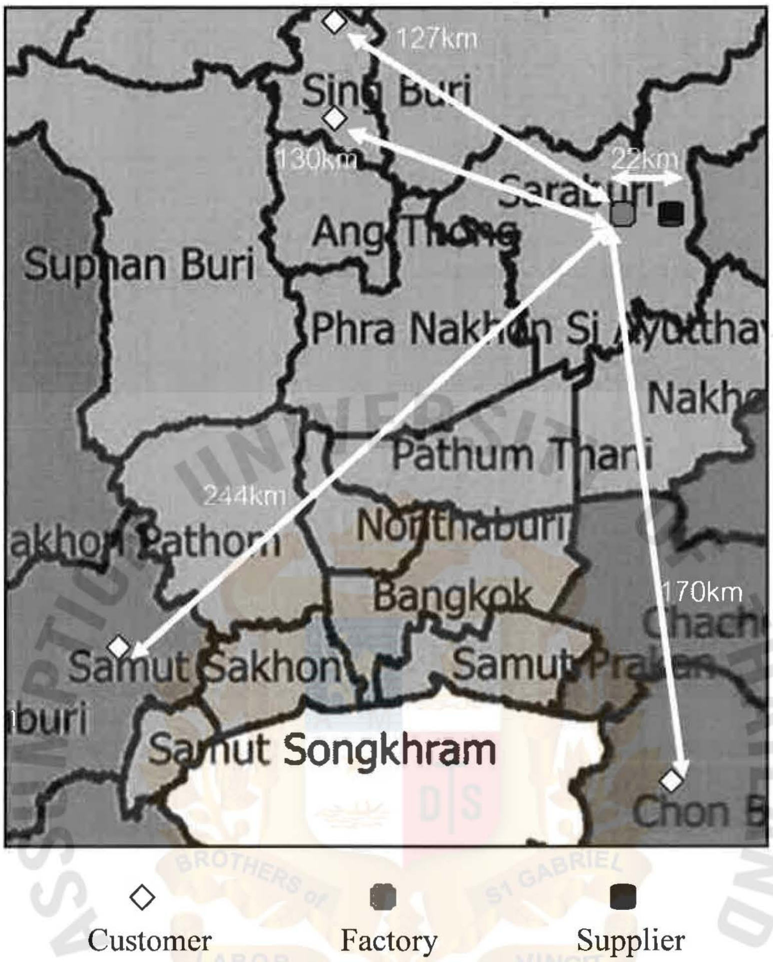


Source: Data from accounting software of Gypsum Fiberboard Co., Ltd.

As a result the owner of Gypsum Fiberboard Co., Ltd. has planned a capacity expansion of four new lime kilns in 2012. Management has designed the new location of the lime kilns to be located next to the current facility. The reason why management chose to expand at the current location is that they could save cost by sharing facilities, equipment and workforce.

Burning lime stone is categorized as a weight loosing and a heavy manufacturing industry. This type of industry usually locates itself next to the raw material source in order to achieve low cost of inbound transportation. The current location of the plant is 22 kilometers away from the raw material source and on average around 200 kilometers away from its customers.

Figure 1.3 Locations of Plant, Supplier and Customers.



It can be seen that the current factory is located fairly near to the raw material source. However Gypsum Fiberboard Co., Ltd still pays around 500,000 baht/month for the transportation of the raw material to its plant. There is a 34% weight loss caused by the production process, this is the cause for the massive inbound transportation cost. In order for Gypsum Fiberboard Co., Ltd to produce its monthly volume of 7,000 tons of lime, it has to acquire 10,500 tons of limestone.

Competitiveness in the hard burned lime industry is extremely high, due to two factors:

1. Price is the main purchasing criterion for the customers in this industry.
2. Price competition between three big suppliers in the market.

The above situation makes it very clear that operating at a low cost is essential in order to survive in this industry. Therefore manufacturing in a location which minimizes the transportation cost could be a strategic advantage for Gypsum Fiberboard Co., Ltd.

The question is: Should Gypsum Fiberboard Co., Ltd expand its four new lime kilns at the current location, as management has suggested, or consider a new location?

1.4 Research Objectives

The aim of this study is to help Gypsum Fiberboard to find an optimal location for the expansion of its four new lime kilns. The motivation is to reduce the overall transportation cost in Gypsum Fiberboard's lime burning activity. This can be achieved by shifting the expansion of the new four lime kilns from the current location to a superior location.

Alternative locations will be examined and compared. The location which has the lowest overall transportation cost will be compared to the current location. Finally a break-even analysis will be performed for the owner of Gypsum Fireboard, to show the feasibility of investing in a new location.

1.5 Scope of the Study

There are many opinions about an optimal location. Usually, both qualitative and quantitative factors are used for an evaluation. However in this study the optimal location is chosen based merely on the location which has the minimum transportation cost.

Alternative locations for the expansion will be considered. The best alternative will be chosen through the help of the load distance method. Finally the alternative location will be compared to the current location.

1.6 Significance of the Study

This paper will be valuable as it aims at giving the owner of Gypsum Fiberboard Co., Ltd information for selecting the optimal location for the four new lime kilns. The consequences of locating at the current location or a new location will be revealed to the owner and management.

Finally, by locating the new lime kilns at an optimal location, Gypsum Fiberboard Co., Ltd will be able to cut excess transportation cost, increase profit, and most importantly gain a competitive advantage over its tough rivals.

1.7 Definition of Terms

Autoclaved Aerated Concrete	Type of a construction brick or called Ytong brick.
Heavy manufacturing	Manufacturing industry that use bulky raw material.
Inbound transportation	Transportation of raw material into the facility.
JIT	Production and inventory control system where materials are procured and products are produced only as required to meet demand.
Lead time	Amount of time between placing an order and receiving it.
Load distance method	Method for determining the coordinates of a facility location.
Optimal Location	Location with low inbound and outbound transportation cost.
Weight losing	In the production process, the weight of the final product is lower than the weight of the raw material going into making that product.

CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH FRAMEWORKS

The Structure of the Literature Review is as follows:

1) Supply chain management and facility models
2) Facility location
3) Type of location problem
4) Historical facility location theories
5) Quantitative facility location theories
   5.1 Load Distance model
   5.2 Center of Gravity model
   5.3 Fixed Charge Location model
6) Qualitative facility location theories
7) Related literature

In this chapter, literature is examined on the information and techniques that are relevant to this research. In the chapter beginning, the broad concept of supply chain is demonstrated and how closely related it is to the concept of facility location.

2.1 Supply Chain Management and Facility Location

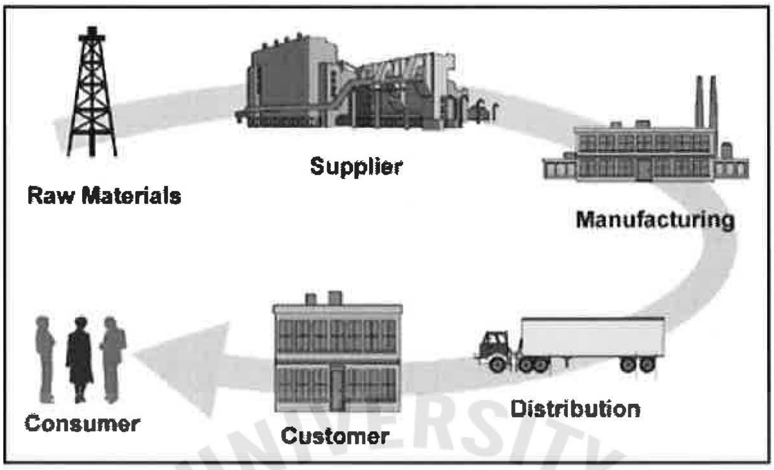
There are a variety of definitions presenting the concept of supply chain. One of the most popular definitions is Mentzer's definition. Supply chain management is the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole (Mentzer, 2001, p.25). Mentzer's definition of supply chain management does not have much to say about the facility location part. Mentzer's definition deals more with the management part of the supply chain. In fact facility location plays an important role in supply chain management, especially at the strategic level.

Langevin and Riopel (2005, p.45) stated that supply chain management entails not only the management of movement of goods but also decisions about:
1) Where to produce, what to produce and how much to produce at each site.
2) What quantity of goods to hold as inventory at each stage of the process.
3) How to share information among parties in the process.
4) Where to locate plants and distribution centers.

Langevin and Riople (2005) showed that there is a clear link between facility location and Supply Chain management. In their paper they have stressed the importance of finding an optimal location: "Location decisions may be the most critical and most difficult of the decisions needed to realize an efficient supply chain. Transportation and inventory decisions can often be changed on relative short notice, however facility location decision are often fixed and difficult to change even in the intermediate term. Inefficient location of production will result in excess cost being incurred throughout the lifetime of the facilities, no matter how well the production plans, transportations options, inventory management, and information sharing decisions are optimized in response to changing conditions" (Langevin & Riopel, 2005, p.40).

The next illustration provides an excellent example of the relationship between facility location and the supply chain:

Figure 2.1 Supply Chain Structure



Source: Adapted from kulogistics.smfnew.com

The location of the supplier, manufacturing or customer, can change the whole picture of the supply-chain. Any location change of one of them affects all parties in the supply chain. Even though the facility location decision is a strategic decision, however there are many operational and tactical issues in supply chain management, which are directly related to it, such as the vehicle routing plan, inventory policies, warehouse capacity and its layout. A typical example would be that an increase in the distribution centers would result in higher inventory cost but usually better customer service.

2.2 Facility Location

Through globalization and the dropping of trade barriers, facility location has become a popular subject in today's business.

Facility location is part of operation research. Pankaj and Micha (1998) have expressed the finding of an optimal facility location as follows. Given a set of demand positions, a distance function, and a parameter p, find a set of p supply points which minimize some distance objective function. The function could be the maximum distance between any demand point and the nearest supply, so that no demand point is too far from a supply, or the sum of distances to the nearest supply. In other words the term facility location can be formulated as a process of identifying the best location for a firm's operation.

According to Frank (2005), the facility location problem has been an important part of operations research since the early 1960's, as it models design decisions on the placement of factories, warehouses, schools, or hospitals to serve a set of customers efficiently.

Bumb (2002) has given an interesting overview of facility location. He has described the facility location problem by four elements:

1. Set of positions where facilities could be built. For every location there must be information of the cost involved in building the facility.
2. Set of demand points (customers) which are assigned to the positions where the facilities may be built. Each demand point has different cost incurred from being served, due to different transportation cost.
3. List of all conditions to be met by the built facilities and demand points.
4. A function that associates each set of facilities with the cost incurred if one would open all the facilities in the set and would assign the demand points to them so that all the requirements are fulfilled. The objective of the problem is to find the facilities to be opened to optimize the given function.

There are many facility location models which do correspond to the four elements of Bumb. Some basic facility location problems will be shown later in this paper.

Mahadevan (2007) has explained that managers must first decide whether they want to build a new facility, expand on site, or relocate to another site. Each choice has its advantage and disadvantage. For example, an onsite expansion has the benefit of keeping people together, reducing construction time and costs, and avoiding splitting up operations. However, as a firm expands a facility, at some point diseconomies of scale set in.

Mahadevan (2007, p.80) has shown a series of steps in selecting a new facility:

1. Identify the important location factors and categorize them as dominant or secondary.
2. Consider alternative regions; then narrow the choices to alternative communities and finally to specific sites.
3. Collect data on the alternatives.
4. Analyze the data collected, beginning with the quantitative factors.
5. Bring the qualitative factors into the evaluation. The site with the highest weighted score is best.

There are many factors that affect the location decision of a facility. Carthy and Atthirawong (2003) came up with the top five major factors that may strongly influence international location decisions. These were: costs, infrastructure, labor characteristics, government and political factors, and economic factors.

Timothy and Clumber (2003) have studied the locating factors of small firms, the top five factors in their study were: closeness to the parent company, proximity to markets, closeness of supplier and resources, good labor climate, and good quality of life.

2.3 Type of Location Problem

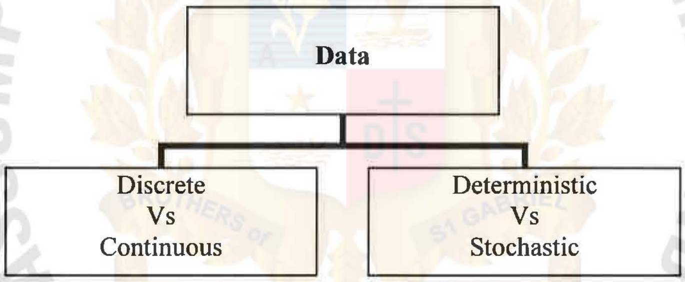
Facility location can be divided into two big categories, which are the location of distribution centers and manufacturing facilities. Most of the literature which could be found, deals with the manufacturing facility location decision.

According to Daskin (1995), there are four types of formulating problems: coverage problems, P-median problems, P-center problems, and fixed charge facility location problems (later referred to as fixed-charge models).

Hamacher and Nickel (1998) have explained that in some location problems the objective is to find a single or multiple center position in order to minimize the maximal distance between a demand point and the facility that is nearest to it. These types of problems are called the K–Center problems, where K is the number of facilities to be located. However, there are few location problems that aim at finding one or more median points in order to minimize the average distance between a demand point and the facility that is nearest to it: these types of problems are called the K-Median problem.

Following, some basic characteristics of the data used in location problems are introduced. For a simple overview, these characteristics are illustrated by Figures:

Figure 2.2 Types of Facility Location Problems



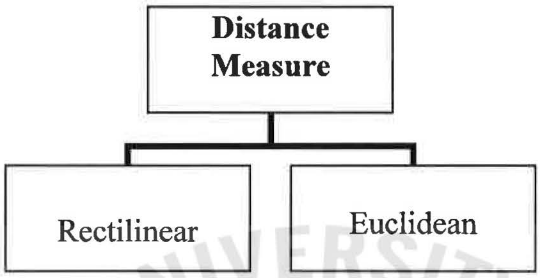
Owen (1999) has explained the concept of discrete facility location problems. In these problems the demand locations and facility locations are restricted. Otherwise, if they are not restricted, these location problems are called continuous facility location problems. Brandeau and Chiu (1989) explained the deterministic and stochastic problems. Deterministic facility locations are problems where all the data used in the calculation are exact. However if there are some parameter values which are given by probability distributions, the problem is considered as stochastic.

A further method to classify the location problem is the distance metric selected. The most common distance metrics are the Rectilinear and Euclidean methods. The formulas for the calculation are as follows:

Distance measure between i and j: Rectilinear: $|x_i-x_j| + |y_i-y_j|$

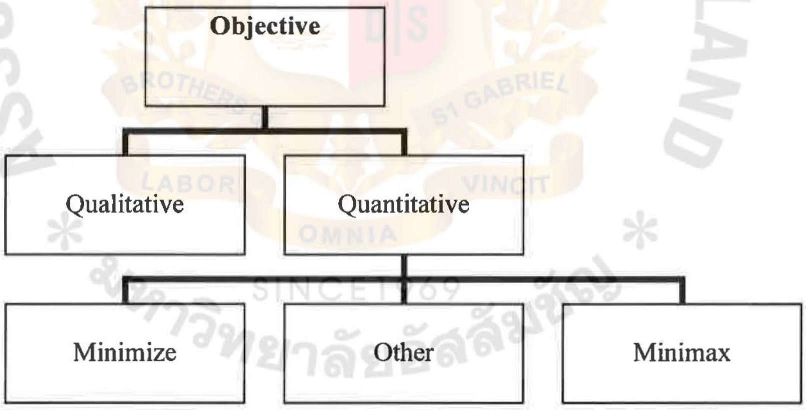
Euclidean: $[(x_i-x_j)^2 + (y_i-y_j)^2]^{0.5}$

Figure 2.3 Classification of Distance Metrics



The last category is the arrangement of objective functions. From all the models in literature that deal with the facility location, these models can be divided into two sub categories, consisting of Qualitative and Quantitative models.

Figure 2.4 Type of Objective Function



The Minimize function aims at minimizing the total cost, and Minimax aims at minimizing the maximum distance between a new facility and existing facilities.

The majority of the models are quantitative; these models mainly take into account the transportation cost of both upstream and downstream transportation costs. The other areas of research are qualitative models. These claim that qualitative factors such as labor skills have a much higher impact in the long run than quantitative factors.

However many studies have agreed that selecting a facility location is a multi objective problem, and it cannot merely be tackled from either the quantitative nor the qualitative model. There have also been studies that tried to connect both. For example Vinh and Devinder (2005) developed a conceptual framework for a site selection, by combining both quantitative and qualitative factors in their decision making.

2.4 Historical Models

The first location theories were formed nearly 200 years ago. Johann Heinrich Von Thuenen, Edgar Hoover and Alfred Weber formulated the first location theories in history.

Von Thuenen (1783-1850) formulated a facility location model which aimed at cost minimization. He applied his theory to farmers in those times. He explained that when the farmers located agriculture points, they should find a location which minimizes the transportation cost, so that they could gain highest profit.

Weber (1868-1958) is considered to be the establisher of modern location theories. His assumption was very similar to Von Thuenen. However Weber's work was more diversified. He came up with many theories, the popular ones being Weber's Least Cost theory and Weber's Weight Losing case. In the Least Cost theory, he tried to find a location for a manufacturing plant which minimizes three categories of cost:

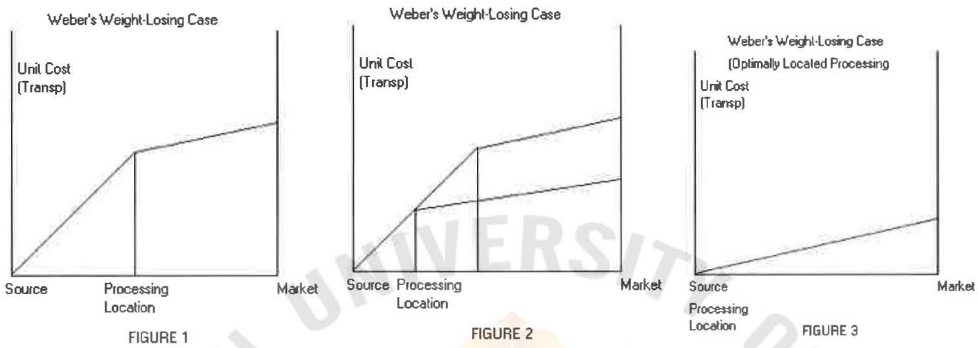
1) Transportation: The location must have the lowest cost in the outbound and inbound transportation. This, according to Weber, is the most important.

2) Labor: The labor cost should be low , so a factory might do better farther from raw materials and markets if cheap labor is available (e.g. China – today).

3) Agglomeration: When many companies come together in the same area (e.g. a city), they can provide assistance to each other through shared talents, services, and facilities (e.g. manufacturing plants need office furniture)

The Weight Losing case is another theory which gained popularity. Weber showed that firms which produce goods less bulky than the raw material used in their production should settle near to the raw material source. And vice versa: firms that produce heavier goods should locate themselves near to their market.

Figure 2.5 Weber's Weight Losing Model



Source: (Birmberg & Love, 1994, p. 36)

Birmberg and Love (1994) illustrated Weber's concept in the above Figure. The processing plant is located between the source and the market. The increase of the transportation cost to the left of the processing plant is the cost of transporting the raw material from its source. The rise in the transportation cost to the right of the processing plant is the cost of transporting the final product. It noticeable that the line on the left of the processing plant has a much steeper slope than the one on the right.

2.5 Quantitative Location Models

There are many models in literature regarding facility location. However it is important to choose the right model for a study. Barry and Chris (2001) have emphasized how important it is for a company to choose the right facility location theory. They said that it is very important that the strategic goals of the company are aligned with the facility location.

In this chapter several quantitative facility location models will be reviewed, beginning with the most common one, the load distance method.

2.5.1 Load Distance Method

The load distance method is the most basic location model found in operation research. (Krajewski & Ritzman 2002; Russel & Taylor 2003). This model is not used to find a location but to evaluate and compare different possible locations. The load distance technique is a mathematical model which selects the optimal location based on the distance and the load between facilities. The distance used in the calculation can be actual mileage, or straight line based on the X ,Y coordinates. As an alternative, the time used to travel between facilities can also be used instead of the distance.

Load distance technique:

1. The load distance for each alternative site will be calculated.
2. The location with the lowest load distance will be chosen as the optimal location.

The load distance formula is as follows:

$$LD = \sum_{i=1}^{n} l_i d_i \qquad (2.1)$$

where,

LD = the load distance value.

l_i = the load expressed as a weight, number of trips, or units being shipped from the proposed site to location i.

d_i = the distance between the proposed site and location i.

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2} \qquad (2.2)$$

where,

(x, y) = coordinates of proposed site

(x_i, y_i) = coordinates of existing facility

2.5.2 Center of Gravity

Center of gravity theory is one of the most famous single facility location models. This theory can be found in many operation management books (Ballou, 2004; Bozarth & Handfield, 2006; Sahin & Sural, 2007).

The center of gravity model is used to locate a facility so that it is central to both demand and supply points. The model is based on the transportation distance and the volume or weight to be transferred.

Following are the steps involved:

1. Construct a grid map of the area.
2. Identify the coordinates of the demand and supply points.
3. Assign the weight or volume to both demand and supply points.
4. Calculate the center of gravity.

The calculation formula for the center of gravity is as follows:

$$X_c = \sum V_i X_i / \sum V_i \quad (2.3)$$

$$Y_c = \sum V_i Y_i / \sum V_i \quad (2.4)$$

Where:

X_c = X coordinate of the center of gravity.

Y_c = Y coordinate of the center of gravity.

V_i = volume of goods transported to or from each i destination

X_i = distances traveled by the goods in X direction

Y_i = distances traveled by the goods in Y direction

However there have been a few criticisms of the center of gravity model. One of the weaknesses is that it does not consider the fixed cost involved in establishing a facility. Also the fact that it does not consider factors such as the availability of roads in selected locations. As a result, this model is not effective for every case, and in some cases modifications have to be made to obtain an optimal solution.

2.5.3 Fixed Charge Location Model

Balinski (1964) is known as the establisher of the fixed charge location theory. Since then much research has been done to formulate facility location models according to Balinski's foundation.

The fixed charge location model is one step ahead of the center of gravity method because it can assign several facility locations, and it takes the facility cost factor into consideration. The fixed charge location model is used to determine the amount and location of the facilities among a set of potential sites. It locates the facilities to serve a set of demand and supply point, so that the fixed cost of locating the facilities and the transportation costs is minimized.

According to Nozick (1998), the fixed charge location model consists of two decision steps:

1. Whether the facility should be located at a candidate site.
2. Assignment of customers to the facility.

Before moving to the formula, the problem parameters of the model are introduced:

- I set of demand points (retailers), indexed by i.
- J set of potential facility locations, indexed by j.
- fj fixed cost of locating a facility at site $j \in J$.
- Di annual demand at demand point $i \in I$
- cij cost per unit to ship from facility site $j \in J$ to demand point $i \in I$

Following are the decision variables:

$X_j =$ 1, if locate a facility at site $j \in J$
or
0, otherwise

$Y_{ij} =$ 1, if demand point $i \in I$ is assigned to a facility at candidate site $j \in J$
or
0, otherwise.

The fixed charge location formula is as follows:

Minimize $$\sum_{j \in J} f_j \chi_j + \sum_{i \in I} \sum_{j \in J} D_i \alpha_j Y_{ij} \qquad (2.5)$$

Subject to

$$\sum_{j \in J} Y_{ij} = 1 \qquad \forall i \in I. \qquad (2.6)$$

$$Y_{ij} \leq \chi_j \qquad \forall i \in I \text{ and } \forall j \in J \qquad (2.7)$$

$$\chi_j \in \{0,1\} \qquad \forall j \in J \qquad (2.8)$$

$$Y_{ij} \in \{0,1\} \qquad \forall i \in I \text{ and } \forall j \in J \qquad (2.9)$$

Constraints: 2.6 Each demand point is assigned to only one facility.

2.7 Demand point assigned to only opened facility

2.8 Single sourcing constraint

2.9 Single sourcing constraint

Finally the above function minimizes the fixed cost of locating the facilities and the transportation cost from demand and supply points to the established facility. The weakness of this theory is that the transportation cost is assumed to be linear and the issue of economy of scale is not included.

2.6 Qualitative Facility Location Model

The traditional literature in location theory has mainly focused on the trade-off between fixed facility location and transportation costs. These location models have failed to include other important costs such as inventory related costs. They also have absolutely neglected qualitative factors. Chen and Sha (2001) have explained that there is a need for companies to concentrate on a combination of both quantitative and qualitative methods in finding the optimal location.

The most popular qualitative facility location method is the weight factor rating model. This model has been discussed in most supply chain management books such as Wisner, Leong and Tan (2005); Russell and Taylor, (2003). The steps in the factor rating model are all very similar. First, of all the factors of importance to the company have to be revealed. Second, each factor has to be rated according to its importance to the company. Third, each alternative location has to be assessed and the identified factors have to be rated for each location. Finally the rated score has to be multiplied by the rating of each factor; the location with the highest score is the superior location according to the qualitative facility location model.

Modern location models have combined the AHP decision model, which is a structured technique for organizing and analyzing decisions, with the factor rating model. This combination makes the factor rating model even more accurate at finding the optimal location.

There have been many researchers trying to investigate the qualitative aspect of facility location. Miller (1993) has stressed the importance of qualitative factors; he listed a few facts which he argued often outweigh the quantitative modeling results. The fact which Miller emphasized the most is the availability of quality labor. He argued that in the future quality would play a main role. Government support and the infrastructure of the location was another area Miller put emphasis on.

Scott (1989) argued that the facility location process involves gathering and analyzing much different information and relating it to the organization's strategic goals. He developed a checklist of the qualitative factors that are involved in a facility location decision:

1. Location of major market.
2. Location of materials and/or service.
3. Availability of labor.
4. Suitable transportation links.

MacCormack, Newmann, and Rosenfield (1994) believed that facility location received only ed exposure in the tegic planning literature. This is due to putting too high an hasis on quantitative factors such as transportation cost and labor cost. Facility location that is based primary on cost factors underestimates the importance of qualitative factors which might provide long term advantages for the company.

2.7 Related Literature

Today there are many advanced models that help organizations to locate their facilities. It could be seen that many of the quantitative mathematical models have only focused on finding the optimal location of the facility based on the customer and supplier transportation cost. They have failed to include the inventory cost which is directly linked to the facility location. Many studies have been aware of the close connection between the management of facility location, inventory, and the transportation policy (Perl & Sirisoponsilp, 1989).

Vaidyanathan (1998) has done research on those theories and came up with a model (FLITNET) to design an optimal distribution network, which analyzes the interdependence of the facility location, inventory, and the distribution. In other words, the model would come up with an optimal solution which considers the trade offs between location, transportation and inventory.

In addition to the linkage of the inventory and the location, there are many other theories which link the location of a facility to other factors such as customer service, and JIT.

Canel & Sidharta (2002) introduced a mathematical model to locate a facility by focusing on the marketing and manufacturing strategies. In this model, different locations' profitability can be compared and analyzed. However the weakness of this model is that some qualitative issues which do not fall into the marketing and manufacturing strategies are neglected.

Saranwong (2009) has used the center of gravity and linear programming models to design a new distributing network for a fast moving consumer good manufacturer. The study came up with a new distribution system which could save the company 8.2 million baht of transportation cost per year. Da Lu (2010) studied how economies of scale impact the decision of facility location. He demonstrated this issue through a case study, that significant cost could be saved by involving the economies of scale factor in the facility location decision. Supaphat (2007) studied the feasibility of establishing new sub-service centers for a pallet rental provider. His study used a heuristic facility location model to solve the problem. His result was that three new sub-service centers could help the pallet rental provider save more than 500,000 baht annually on transportation cost.

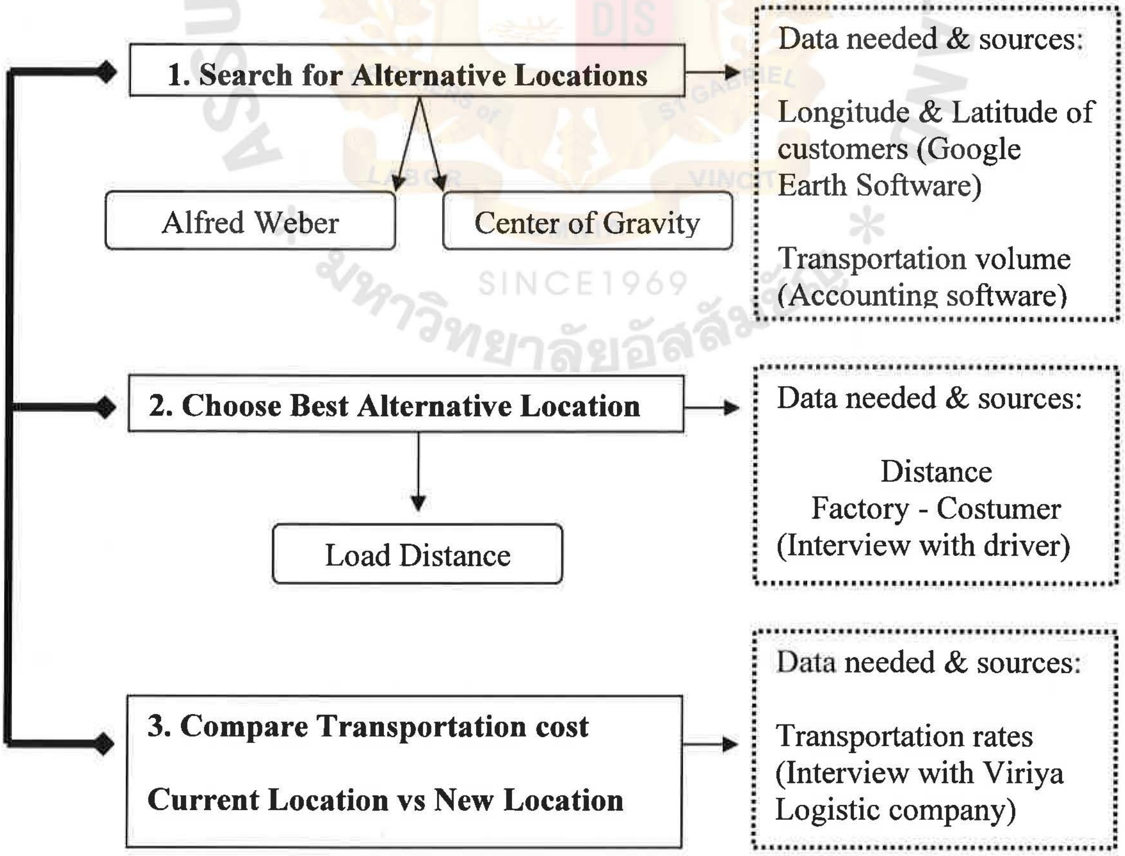
Melo, Nickel, and Saldanha (2009), have summarized in a table the studies which combined the different areas with the determination of a facility location. In their findings they found 35 theories that combined inventory with facility location, 24 theories that combined production with facility location, 19 which combined capacity with facility location, 7 which combined routing with facility location, 6 combined transportation modes with facility location, and 7 which combined procurement with facility location. There are even many other areas which have been combined with the facility location problem. Helander and Melachrinoudis (1997) developed a model to find a location which aimed at reducing material transportation accidents.

CHAPTER III

METHODOLOGY

In the following chapter, the method for discovering a location with minimum transportation cost is revealed. The quantitative approach is applied in this section. In the first step reasonable alternative locations will be introduced through the help of the Weber theory and the center of gravity model. Then both locations will be compared, and the superior location will be chosen by the load distance theory. Finally the transportation cost of the current location of Gypsum Fiberboard Co., Ltd. will be compared to the new location. The structure of the methodology is illustrated in the Figure below.

Figure 3.1 Structure of Methodology



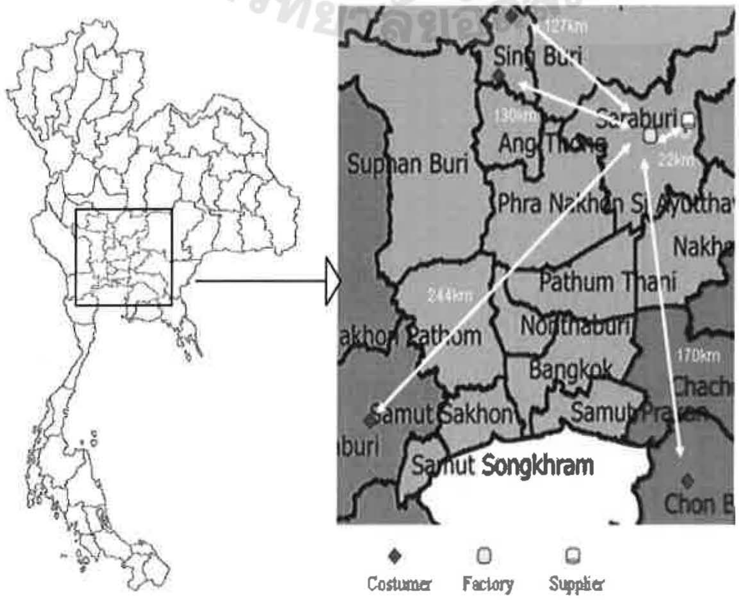
3.1 Data Collection

In this chapter, the data presented have been obtained through following methods. The Longitude and Latitudes data have been acquired by taking the location map of the supplier/ customers and positioning them in the Google Earth software. The X and Y coordinates have been discovered through overlaying an X/Y coordinate system over the map. Next, the transportation volume has been extracted from the accounting software. The transportation volume between the factory and each customer has been set through taking the average of the last six-month history volume of each customer. The distance between the factory and each customer has been obtained through interviews with the truck driver at each location. The data is actual road distance data. Finally the transportation cost has been gathered through interviews with Viriya Logistic, the transportation company of Gypsum Fiberboard Co., Ltd.

3.2 Current Location

The Figure below shows the locations of the current factory its raw materials source and supplier.

Figure 3.2 Location of Current Factory, Customers and Supplier.



3.3 Center of Gravity Method

First of all some alternative locations have to be established. The first method used to find a potential location for the expansion is the center of gravity method. The center of gravity method is used to find a location that minimizes the transportation cost between inbound and outbound. It treats transportation cost as a linear function of distance and quantity.

Following are the steps employed in finding the center of gravity:

1. The Longitude and Latitude of current supplier and customers are collected.

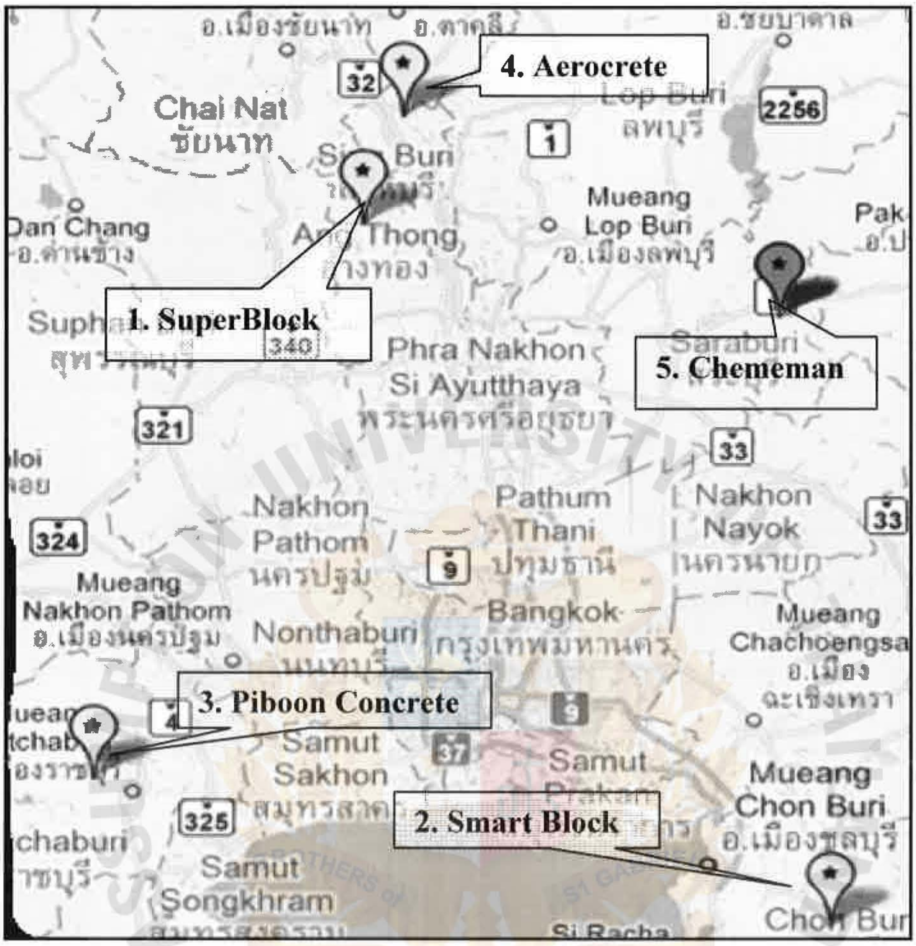
Table 3.1 Customer and Supplier Locations

Company	Province	Latitude	Longitude
Customer			
1. Superblock Public Company Limited	Singburi	14°47'39.33	100°16'41.17
2. Smart Block Co., Ltd	Chonburi	13°13'30.15	101°13'43.88
3. Piboon Concrete Co., Ltd	Ratchaburi	13°33'20.25	99°43'32.67
4. Aerocrete (Thailand) Co., Ltd	Singburi	15° 1'57.39	100°21'32.35
Supplier			
5. Chememan Company Limited	Saraburi	14°35'26.48	101° 7'23.49

Source: Google Earth Software

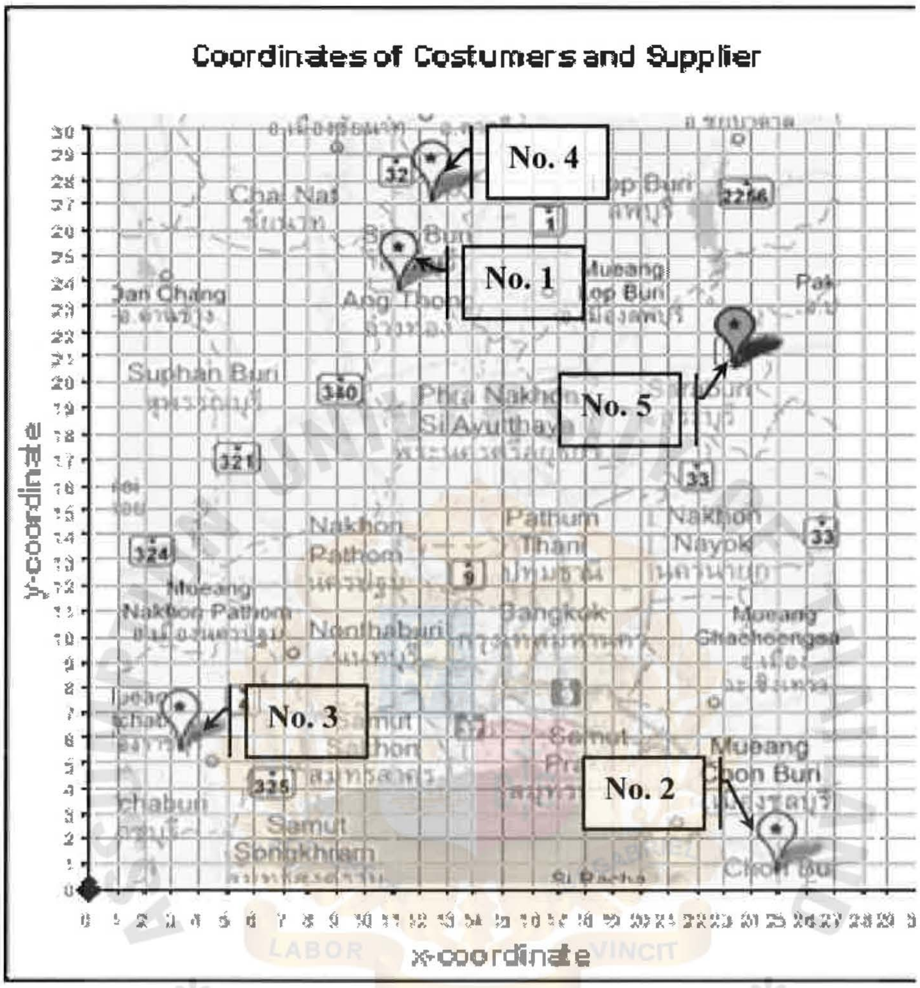
2. The Locations of both Supplier and Customers are marked into the map according to their Longitude and Latitude values. The map has to be magnified for higher accuracy.

Figure 3.3 Location of Suppliers and Customers



3. A coordinate system is overlaid on the map to determine the relative locations. The locations of the firm's existing customers and supplier are then converted into X and Y coordinates. See Figure 3.3.

Figure 3.4 Map of Supplier and Customers Overlaid with Coordinates



In the next table the coordinates obtained are shown.

Table 3.2 Customers and Supplier Coordinates

No	Company Name	X	Y
1	Superblock Public Company Limited	12.4	27.0
2	Smart Block Co., Ltd	25.0	0.6
3	Piboon Concrete Co., Ltd	3.4	5.5
4	Aerocrete (Thailand) Co., Ltd	11.1	23.7
5	Chememan Company Limited	23.4	20.8

4. The average shipping volume for each location is approximated:

The data has been obtained from an interview with the sales personal of Gypsum Fiberboard Co., Ltd.

Table 3.3 Monthly Transportation Volume

Superblock	Smart Block	Piboon Concrete	Aerocrete	Chememan
2,500 ton	2,000 ton	1,500 ton	1,000 ton	10,500 ton

Source: Gypsum Fiberboard Co., Ltd. accounting software.

5. The data for the center of gravity calculation has been prepared.

Table 3.4 Data for Center of Gravity Calculation

Location	Monthly shipping volume	Coordinates		Weighted Coordinates	
		X	Y	X	Y
Chemiman	10,500	23.4	20.8	245,700	218,000
Superblock	2,500	12.4	27	31,000	67,500
Smart Block	2,000	25	0.6	50,000	1,200
Piboon Concrete	1,500	3.4	5.5	5,100	8,250
Aerocrete	1,000	11.1	23.7	11,100	23,700
Total	17,500			342,900	319,050

Since the quantity shipped from and to each destination is not equal, therefore a weighted average is applied, where the weights is the quantities to be shipped.

The X and Y coordinates for the center of gravity are obtained by summing the weighted coordinates and dividing that by the monthly shipped volume. Following is the formula:

$$X_c = \Sigma V_i X_i / \Sigma V_i \qquad (3.1)$$

$$Y_c = \Sigma V_i Y_i / \Sigma V_i \qquad (3.2)$$

where:

X_c = X coordinate of the center of gravity.

Y_c = Y coordinate of the center of gravity.

V_i = volume of goods transported to or from each i destination

X_i = distances traveled by the goods in X direction

Y_i = distances traveled by the goods in Y direction

Center of gravity calculation: Xc = 342,900 / 17,500 = <u>19.59</u>

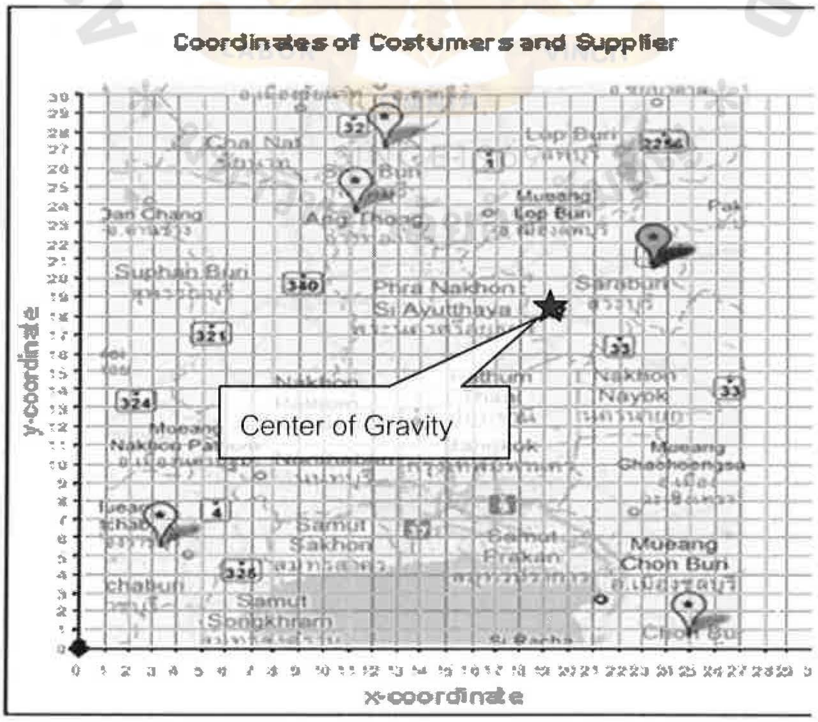
Yc = 319,050 / 17,500 = <u>18.23</u>

Therefore the optimal location according to the center of gravity method is:
X coordinate = 19.59 and Y coordinate = 18.23

The location of the center of gravity according to the X and Y coordinates is as follows:

Province:	Saraburi	City:	Nong Saeng
Town:	Nong Kwai So	Road:	no. 3041

Figure 3.5 Center of Gravity Position



3.4 Weber's Theory

Alfred Weber is considered to be the establisher of the foundation of location theories. Please see Literature Review (2.4 Historical facility location models). Today most industries that fall into the category of heavy manufacturing and weight losing locate themselves next to the raw material source, as Weber suggested.

In the search for an alternative location, Weber's Weight Losing theory has been taken as an alternative in locating the proposed expansion.

Reason for choosing Weber's Weight Losing theory:

1. Weight loss of 35% in production of Lime
   (Due to the carbon dioxide gas which leaves the stone)
2. High inbound transportation cost.
3. Cheap land price at raw material site.

Regarding to Weber's Weight losing theory, the optimal location should be at the raw material site.

After a field study to Chememan Company Limited, the raw material source, it has been found that there is plenty of land next to the source. The average land price in that area is cheap, because the environment is dusty and detonations are applied to the extraction of the limestone.

The land lying next to the source at the east side is chosen for the alternative location.

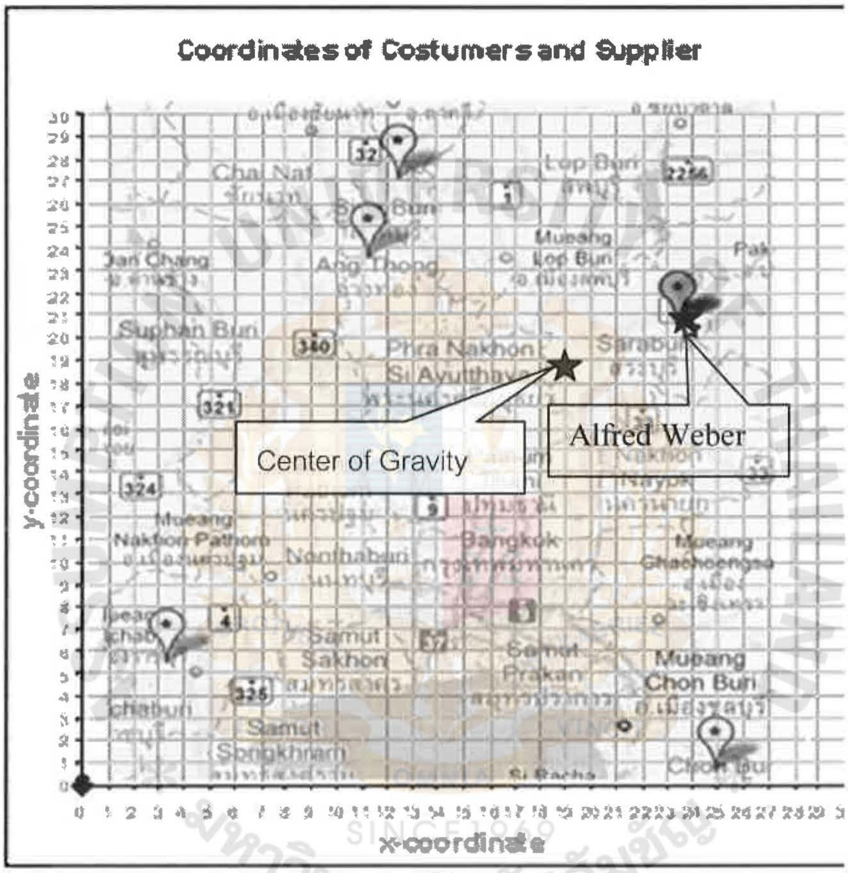
Position: Latitude: 14°35'25.27 Loangtitude: 101° 7'33.41

Coordinates are: X 23.6 and Y 20.6

The position for a Weber location is as follows:

Province:	Saraburi	City:	Kaeng Khoi
Town:	Thap Kwang	Road:	no. 2

Figure 3.6 Weber and Center of Gravity Position



3.5 Load Distance Method

The load distance method is a mathematical model which is used to evaluate and select locations based on proximity factors. The common formulas used by the load distance are either the Rectilinear or the Euclidean method. However both of these methods are rough distance calculations, they do not represent the actual distance in the real situation. Therefore in this case, the actual distance has been collected by real road distance to ensure the ultimate solution.

The steps involved in the load distance calculation are:

1. Collecting distance between: Firm-Customers, and Firm–Supplier
2. Estimating the load of Customers and Supplier.
3. Calculating Load distance

1. <u>Collected Data on Distances</u>

Table 3.5 Distance from Center of Gravity to Customers and Supplier.

Company	Distance (km)
Superblock Public Company Limited	105
Smart Block Co., Ltd	144
Piboon Concrete Co., Ltd	218
Aerocrete (Thailand) Co., Ltd	118
Chememan Company Limited	22

Source: Interview with driver at Gypsum Fiberboard Co., Ltd.

Table 3.6 Distance from Weber Position to Customers and Supplier.

Company	Distance (km)
Superblock Public Company Limited	127
Smart Block Co., Ltd	166
Piboon Concrete Co., Ltd	240
Aerocrete (Thailand) Co., Ltd	140
Chememan Company Limited	2

Source: Interview with driver at Gypsum Fiberboard Co., Ltd.

2. <u>Estimated Load</u>

Next the approximation of sales and purchasing quantity is shown. This data has been obtained from an interview with the sales personnel of Gypsum Fiberboard.

Table 3.7 Projected Loads between Facility and Customers/Supplier.

Company	Ton/month
Superblock Public Company Limited	2,500
Smart Block Co., Ltd	2,000
Piboon Concrete Co., Ltd	1,500
Aerocrete (Thailand) Co., Ltd	1,000
Chememan Company Limited	10,500

In order to make the calculation uncomplicated, the customer demand per month is transferred into load factors. This is done by dividing all the demand quantities by 1,000.

Table 3.8 Load Factors

	Chememan	Aerocrete	Piboon	Smart Block	Superblock
Load factor	10.5	1	1.5	2	2.5

3. Load Distance Calculation

Finally the distance of each location is multiplied by the load factor; the location which has the minimum load distance is the superior location.

Table 3.9 Load Factor Calculation for Center of Gravity

Company	Distance	Load Factor	Sum
Superblock Public Company Limited	105 km	2.5	262.5
Smart Block Co., Ltd	144 km	2	288
Piboon Concrete Co., Ltd	218 km	1.5	327
Aerocrete (Thailand) Co., Ltd	118 km	1	118
Chememan Company Limited	41 km	10.5	430
		sum	**1425.5**

Table 3.10 Load Factor Calculation for Weber Position

Company	Distance	Load Factor	Sum
Superblock Public Company Limited	151 km	2.5	302
Smart Block Co., Ltd	191 km	2	382
Piboon Concrete Co., Ltd	265 km	1.5	397.5
Aerocrete (Thailand) Co., Ltd	148 km	1	148
Chememan Company Limited	2 km	10.5	21
		sum	**1250.5**

The Weber location method has the minimum Load-distance (1250).

Therefore, according to the load distance method, the superior location is the Weber location.

3.6 Compare Locations

In the following section the total transportation cost of the current location will be calculated and compared to the best alternative location

Transportation cost between:

1. Raw material source – Current Location – Customers
2. Raw material source – Weber Location – Customers

3.6.1 Total Transportation cost of Current Location

Inbound Transportation

Table 3.11Distance between Raw Material Source and Current Location

Raw Material Source	Current Location	Distance (km)
Chememan Company Limited	Gypsum Fiberboard Co., Ltd.	22

Figure 3.7 Distance between Current Location – Raw material

Every year Gypsum Fiberboard Co., Ltd. has an auction for the inbound transportation job. The lowest bidder in 2011 is Viriya Logistic. Following is the inbound transportation cost in 2011.

Table 3.12 Current Inbound Transportation Cost per month

Transportation Company	Monthly Volume Tons	Transportation cost baht/ton	Transportation baht/month
Viriya Logistic	10,500	48	504,000

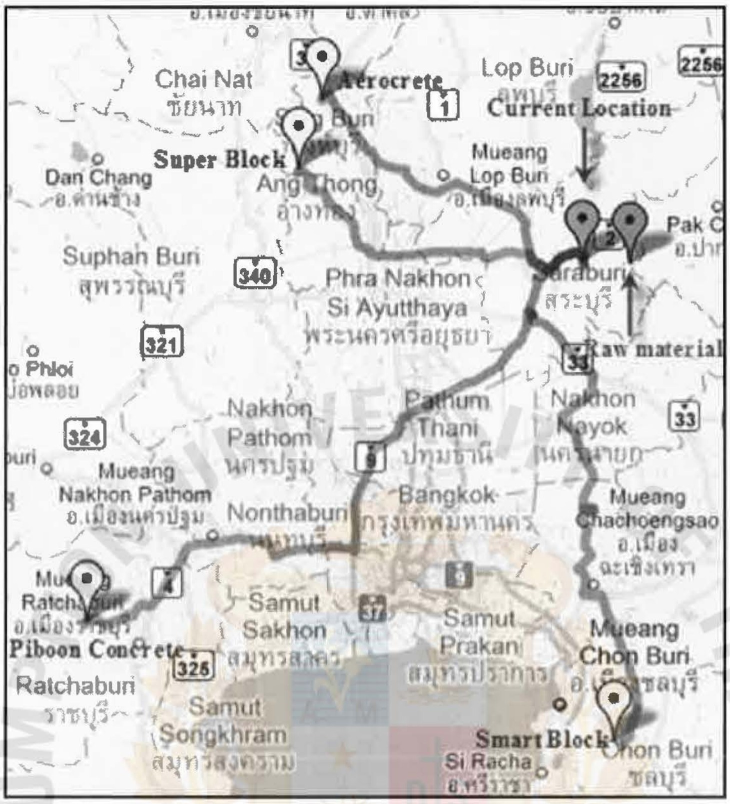
Source: Viriya Logistic Company

<u>Outbound Transportation</u>

Table 3.13 Distance between Current Location and Customers

Customer	Province	Distance (km)
Superblock Public Company Limited	Singburi	129
Smart Block Co., Ltd	Chonburi	169
Piboon Concrete Co., Ltd	Ratchaburi	243
Aerocrete (Thailand) Co., Ltd	Singburi	126

Figure 3.8 Distance between Current Factory - Customers



Gypsum Fiberboard Co., Ltd uses the service of two transportation companies for their outbound transportation, consisting of: Viriya Logistic company and Phatara company. Following, the current outbound transportation cost is shown.

Figure 3.14 Monthly Outbound Transportation Cost of Current Location

Customer	Cost Baht/ton	Approximate ton/month	Transportation cost baht/month
Superblock Public Company	220	2,500	550,000
Smart Block Co., Ltd	260	2,000	520,000
Piboon Concrete Co., Ltd	320	1,500	480,000
Aerocrete (Thailand) Co., Ltd	215	1,000	215,000
Total			**1,765,000**

Source: Viriya Logistic Company

The total transportation cost of the current location is:

504,000 + 1,765,000 = 2,269,000 baht/month

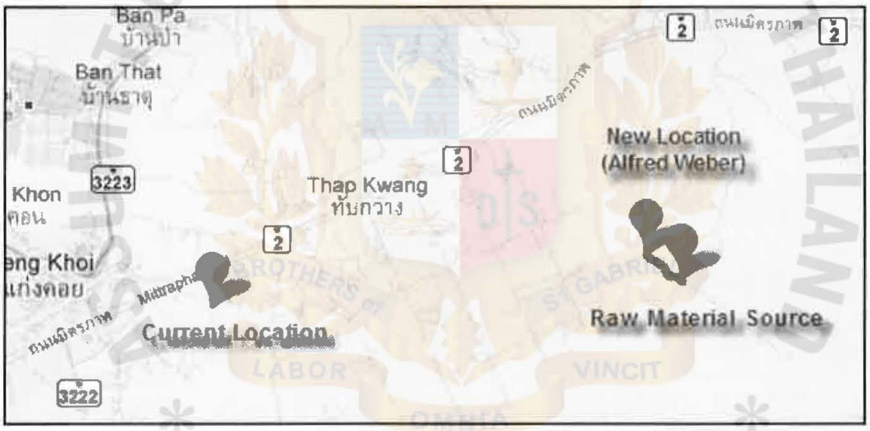
3.6.2 Total Transportation cost of Weber Location

Inbound Transportation

Table 3.15 Distance between Raw Material and Weber Location

Raw Material Source	Weber Location	Distance (km)
Chememan Company Limited	New Location	2

Figure 3.9 Distance between Current Location – Raw material



The transportation cost for transporting the raw material to the new location has been offered by Viriya Logistic Company at 5 baht per ton.

Table 3.16 New Location Inbound Transportation Cost per month

Transportation Company	Monthly Volume Tons	Transportation cost baht/ton	Transportation baht/month
Viriya Logistic	10,500	5	52,500

Source: Viriya Logistic company

Outbound Transportation

Table 3.17 Distance between New Location and Customers

Customer	Province	Distance (km)
Superblock Public Company Limited	Singburi	151
Smart Block Co., Ltd	Chonburi	191
Piboon Concrete Co., Ltd	Ratchaburi	265
Aerocrete (Thailand) Co., Ltd	Singburi	148

Figure 3.10 Distance between New Location - Customers

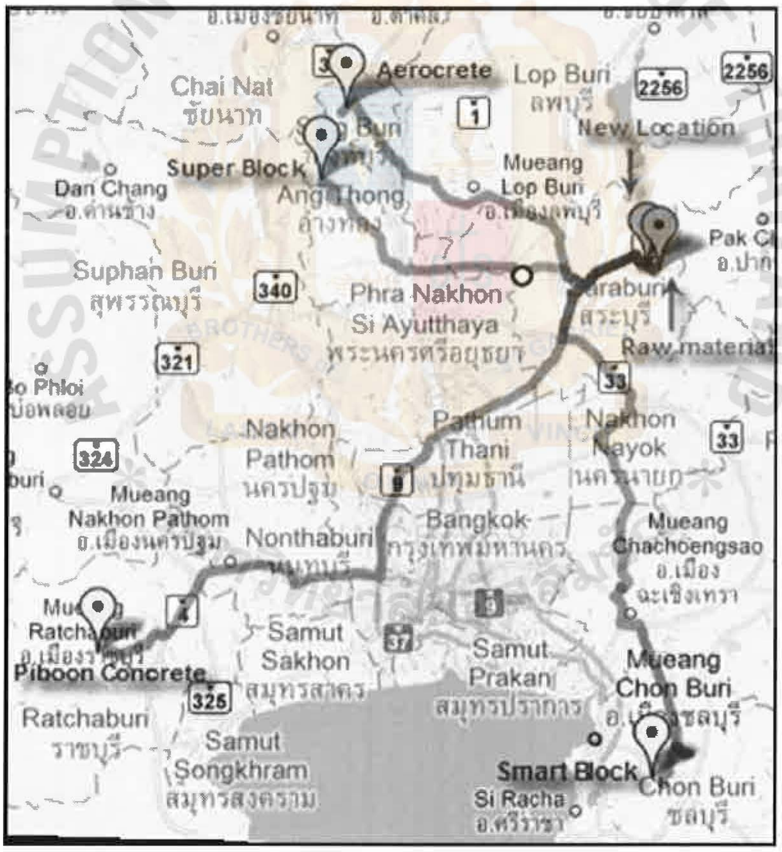


Table 3.18 Monthly Outbound Transportation Cost of New Location.

Customer	Cost Baht/ton	Approximate ton/month	Transportation cost baht/month
Superblock Public Company	225	2,500	562,500
Smart Block Co., Ltd	265	2,000	530,000
Piboon Concrete Co., Ltd	325	1,500	487,000
Aerocrete (Thailand) Co., Ltd	220	1,000	220,000
Total			1,799500

The total transportation cost of the new location is:

52,500 + 1,799,500 = 1,852,000 baht/month

3.7 Conclusion

Finally the total transportation costs of the new location and the current location are compared:

Current Location	2,269,000 baht/month
New Location	1,852,000 baht/month
Difference	**417,000 baht/month**

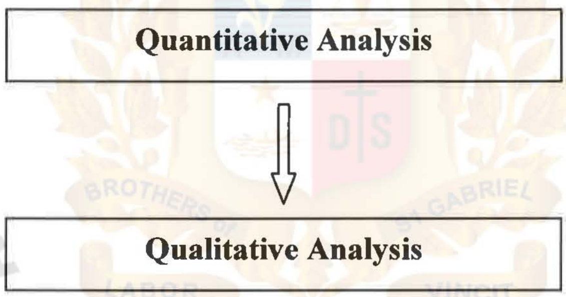
As a result, the total monthly transportation cost of the new location is 417,000 baht/month lower than the current location.

CHAPTER IV

RESULT AND ANALYSIS

In the following chapter the possibility of moving the expansion to a new location will be analyzed in both the quantitative and qualitative aspects. The quantitative analysis is performed using the following calculations: 1. NPV calculation. 2. IRR calculation. 3. Payback period. The qualitative analysis is done by gathering qualitative factors that are of importance to management and owner in managing the new project. Interviews with both the owner and managers were held.

Figure 4.1 Structure of Result and Analysis



4.1 Quantitative Analysis

In the following section, the financial feasibility of expanding the factory at the new location will be revealed. This is done through first gathering the benefits and expenses of the new location, then the NPV, IRR and payback period will be calculated for this investment.

4.1.1 Benefit

The total transportation cost of the current location and the new location has been compared in the previous chapter. The total transportation cost of the current location is 2,269,000 baht/month, whereas the total transportation cost of the new location per month is only 1,852,000 baht.

As a conclusion, Gypsum Fiberboard Co., Ltd. could save 417,000 baht per month on transportation cost, if it considers expanding at the new location.

Benefit per year = 417,000 baht/month x 12 months = 5,004,000

4.1.2 Expense

There is some additional investment required in order for Gypsum Fiberboard Co., Ltd to expand at the new location. The costs are separated into fixed investment cost and variable cost. The fixed investment cost and variable cost have been gathered through interviews with project engineers. The vehicle prices have been acquired from the purchasing department of Gypsum Fiberboard Co., Ltd. The building costs have been calculated with the help of the Thai Governmental cost estimates of 2011. The land price has been acquired through an onsite visit. Finally the salary cost has been obtained from the human resource department of Gypsum Fiberboard Co., Ltd.

Table 4.1 Fixed Investment Cost

Vehicle:	Pick-up (Toyota Vigo)	450,000 baht
	Wheel Loader (Hitachi LX 80)	3,400,000 baht
	Excavator (Hitachi Zaxis 200)	3,800,000 baht
Building:	Warehouse (20m x 20m, 7,000 baht/m^2)	2,800,000 baht
	Road (6m x 200m, 1200baht/ m^2)	1,800,000 baht
	Office (6m x 8m, 14,000 baht/m^2)	672,000 baht
	Truck weight scale	450,000 baht
	Fence (500m x 3m, 260 baht/ m^2)	390,000 baht
	Electricity Foundation (Transformer etc.)	900,000 baht
Land:	Land cost (16,000m^2, 25 baht/ m^2)	1,000,000 baht
	Land improvement (Level Ground)	200,000 baht
	Total fixed investment cost	**15,862,000 baht**

Table 4.2 Variable Cost

Employee:	Secretary (1 person)	12,000 baht/month
	Manager (1 person)	19,500 baht/month
	Guard (2 persons)	18,000 baht/month
	Total variable cost	**49,500 baht/month**
	49,500 x 12 months	**594,000 baht/year**

4.1.3 NPV Calculation

This calculation helps to financially determine whether it makes sense to invest into the new location. The NPV shows the value of the investment by taking into account the initial investment and the present value of future cash flow. If the NPV value is positive, the investment is attractive otherwise it is not. The length of the project has been determined to be 5 years with a cost of funding of 7%. The cost of funding has been obtained from the loan conditions of Krung Thai Bank Public Company on April 30, 2011. (http://www.ktb.co.th/upload/interest_rates/loan/loan30_04_54.pdf)

$$\text{NPV} = \sum_{t=0}^{T} \frac{Nt}{(1+i)^t} \tag{4.1}$$

Table 4.3 NPV Calculation

Year	Benefit	Expense	Net	PV (7%)
1	5,004,000	16,456,000	-11,452,000	-10,702,804
2	5,004,000	594,000	4,410,000	3,851,865
3	5,004,000	594,000	4,410,000	3,599,874
4	5,004,000	594,000	4,410,000	3,364,368
5	5,004,000	594,000	4,410,000	3,144,269

NPV = 3,257,572

The NPV value is positive; therefore Gypsum Fiberboard Co., Ltd. should invest in the new location.

4.1.4 IRR Calculation

The IRR calculation shows the profitability of investing in the new location. It shows the discount rate or cost of capital at which the net present value of cost and benefit are equal. The IRR can be calculated by using the NPV formula and inserting a number for the interest rate until the NPV value is close to zero. However this trial and error method consumes time. In this paper the IRR formula in Excel is applied, then the IRR value obtained is double checked by replacing it in the NPV formula.

IRR excel formula: =IRR (sum of net, 0.1)

IRR value obtained = 19.83552 %

The IRR value of 19.83% is higher than the source of funding which is 7%, which means that the investment is feasible.

Table 4.4 IRR Calculation Data

Year	Benefit	Expense	Net
1	5,004,000	16,456,000	-11,452,000
2	5,004,000	594,000	4,410,000
3	5,004,000	594,000	4,410,000
4	5,004,000	594,000	4,410,000
5	5,004,000	594,000	4,410,000

Double check:

Table 4.5 IRR Calculation

Year	Benefit	Expense	Net	PV (7%)
1	5,004,000	16,456,000	-11,452,000	-9,556,432
2	5,004,000	594,000	4,410,000	3,070,913
3	5,004,000	594,000	4,410,000	2,562,606
4	5,004,000	594,000	4,410,000	2,138,436
5	5,004,000	594,000	4,410,000	1,784,476

NPV = 0

By setting the cost of capital or interest at 19.83552 %, the NPV value is 0. Therefore the IRR at 19.843552 % is correct.

4.1.5 Payback period Calculation

The payback period determines the amount of time it takes to break even on investing in the new location. In the following Table, the expenses and benefits of investing in the new location are summarized.

Table 4.6 Payback Period Calculation

Year	Benefit	Expense	Sum	Balance
1	5,004,000	16,456,000	-11,452,000	- 11,452,000
2	5,004,000	594,000	4,410,000	- 7,042,000
3	5,004,000	594,000	4,410,000	- 2,632,000
4	5,004,000	594,000	4,410,000	1,778,000
5	5,004,000	594,000	4,410,000	6,118,000

The payback period calculation is shown below:

Payback period = Last year where balance is negative + (Value of last year where balance is negative/ Value of first year where sum is positive)

Payback period = 3 + (2,632,000 / 4,410,000) = 3.6

= 3 + (0.6*12) = 3 years and 7 months

4.2 Qualitative Analysis

There are both positive and negative qualitative factors concerning expanding at the new location. These factors have been gathered through interviews with the owner and managers of Gypsum Fiberboard Co., Ltd. In the next Table, the Qualitative factors are summarized:

Table 4.7 Qualitative Factors

Positive Factors	Negative Factors
1. Produce Lime at low cost	1.Little owner presence causes:
	1.1 Production output
2. Short lead time in acquiring raw material.	1.2 Product &Process improvement
	1.3 Internal Corruption
	2. Ineffective management
3. Spread risk	3. Higher risk

4.2.1 Positive side

Produce Lime at Low cost: Due to the low inbound transportation cost, the production cost of the lime decreases. This increases the competitiveness of the company against its rivals.

Short lead time in acquiring raw material: Due to closeness of raw material source, the new factory can keep less raw material inventory. The management of raw material will be more straightforward.

Spread risk: Gypsum Fiberboard Co., Ltd. will have two production sites; production failure at both sites at the same time is almost eliminated. Therefore if one of the sites has a production problem, the other site can compensate. Risks that are spread consist of: Electricity breakdown, labor boycott, explosion, fire, and natural disasters.

4.2.2 Negative side

Little Owner's presence at factory: The owner of Gypsum Fiberboard Co., Ltd. graduated in Germany with a master degree in engineering and architecture. He is highly knowledgeable about the lime burning business. The current factory and the whole lime burning process have been designed by him. His management style is autocratic; he believes that his presence at the production site has a positive impact on the following issues:

1. Production Output
2. Process and Product Improvement
3. Internal Corruption

Ineffective management: Gypsum Fiberboard Co., Ltd. is a medium size family business, and any decision has to be made by top management. Top management including the owner, work in the head office at the current location. If there is any decision to be made at the new location operation, top management would have to do it. Management decision-making will be less effective, because they are not at the site to see the problem by themselves.

Higher Risk: Expanding at the new location requires higher investment, so there is higher financial risk. There is also more hidden risk involved in expanding at a new location, for example, the community in that area might protest against the project.

Finally, it is very complicated to conclude whether the positive factors outweigh the negative factors. However there is a tendency that the positive side outweighs the negative side. In order to make a clear decision, one must have knowledge about the whole situation and be able to predict whether Gypsum Fiberboard Co., Ltd. can successfully run their operation at the new site under the constraint of the negative factors.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Summary of the Findings

This study found a location which minimizes the total transportation cost for Gypsum Fiberboard Co., Ltd. This new location is located next to the raw material source of Gypsum Fiberboard, as shown in Figure 5.1

Figure 5.1 New Location

The total transportation cost of the new location has been calculated and compared to the current location. Following, are the results.

Table 5.1 Total Transportation Cost

	Current location	New Location
Outbound Transportation	1,765,000 baht/month	1,799,500 baht/month
Inbound Transportation	504,000 baht/month	52,500 baht/month
Total	**2,269,000 baht/month**	**1,852,000 baht/month**

The total transportation cost of the new location is 417,000 baht/month lower.

The financial feasibility for investing into the new location has been revealed. The results follow in Table 5.2.

Table 5.2 Financial Feasibility

NPV	**3,257,572 baht**
IRR	**19.84%**
Payback Period	**3.6 years**

All the above figures support investment in the new location.

5.2 Conclusion

As previously stated, facility location is one of the most important strategic decisions in supply chain management. It requires a very high investment and it cannot be altered in the short term. The aim of this study is to find a location with minimum transportation cost for Gypsum Fiberboard Co., Ltd. expansion. Through the use of several facility location models and techniques, a superior location has been discovered in this study. The new location could save up to 417,000 baht per month on transportation cost. This study goes a step further by studying the feasibility of investing in the new location. The additional fixed investment cost and the additional variable cost in moving to the new location has been gathered. The NPV, IRR and Payback period have been then calculated for this investment. As a result, all these values are favorable for investing in the new location. Qualitative factors regarding investing in the new location have also been revealed. There is a tendency that the positive factors outweigh the negative factors.

As a final point, both qualitative and quantitative factors analyzed in this study, favor the proposal for Gypsum Fiberboard Co., Ltd. to invest in the new location.

Theoretical Implications

This study has mainly explored the literature of facility locations. Both quantitative and qualitative theories and models have been explored. However the quantitative facility location theory has been the main area of this study This study especially supported the weight losing concept of Alfred Weber. It has clearly shown that manufacturing companies that are in the category of weight losing, can significantly reduce their transportation cost in shifting their facility to the raw material source. From a theoretical perspective, this study has contributed to the increase of literature regarding facility location. Other researchers who study facility location could take this study as a typical example of finding an optimal location for heavy manufacturing industries and companies that produce weight losing goods.

Managerial Implications

This study demonstrated the importance of choosing a location for Gypsum Fiberboard Co., Ltd. It made the owner and management of Gypsum Fiberboard realize the massive amount of transportation cost they could save if the new expansion would be shifted to a superior location. This study continued by showing the owner and management of Gypsum Fiberboard the feasibility of investing in the superior location. The NPV, IRR and Payback period have been calculated and showed that Gypsum Fiberboard should invest in the new location. This study is also an excellent example for companies that are in the heavy manufacturing industry.

5.2 Limitations and Recommendations

Facility location models

Due to the broad scope of this study and time limitation, the optimal location in this study derived from only three facility location models, consisting of the Center of gravity model, Alfred Weber's theory and the Load distance model. There are many other interesting facility location models which could be used for finding the optimal location, such as the Mixed Integer Programming model.

Demand variation

The calculation in this study did not address the issue of uncertain demand. It would be interesting to see how the optimal location would change if the forecasted demand changes.

Fuel fluctuation

Fuel cost is the most important factor in calculating the attractiveness of the new location. Further studies could simulate models for cases where the fuel price increases and decreases. As a result, it could be seen at what fuel price the investment would not be attractive.

Benchmark

The aim of this study was to find a location for the expansion so that transportation cost could me minimized. However, the ultimate goal is to gain a competitive advantage over the competitors. Further studies could study the transportation cost of the three competitors and compare them to the new location of Gypsum Fiberboard Co., Ltd. As a result it could be seen whether the new location provides a true strategic advantage for Gypsum Fiberboard Co., Ltd.

Qualitative analysis

Due to the time constraint, the quantitative factors gathered in this study have not been rated and assessed for choosing the optimal location. Further studies could include the qualitative aspect in the optimal location selection. This could be done by identifying the factors of importance, rate each factor of its importance, asses each location and rate it, and finally multiply the score and choose the best score.

Customer position

This study selected a new optimal location based on the current customers. The study assumed the location of the customers to be fixed. However there are other consumers out in the market that might become future customers of Gypsum Fiberboard Co., Ltd. Further studies could use models of different groups of customers and observe whether and how the optimal location would change.

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OPTIMAL FACILITY LOCATION:
A CASE OF GYPSUM FIBERBOARD CO., LTD.

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ADVISOR'S STATEMENT

I confirm that this thesis/project has been carried out under my supervision and it represents the original work of the candidate.

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