IDENTIFYING AN OPTIMAL FACILITY LOCATION FOR A FACTORY

Arne Suthamphong*
Department of Industrial Management, Assumption Univesity

Abstract

This purpose of this research was to help a Thai lime-burning company to find an alternative factory location for its expanding business, which would minimize the transportation cost. Such factories usually locate next to the raw material source, but the current location was 20 km 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, were used, and with the help of the load distance method, the best alternative location was chosen. The result was that the new location could save up to 5 million baht per year on transportation cost. The additional cost of moving the existing facility to the new location was calculated, for fixed and variable costs. The NPV, IRR and Payback period were also calculated. All the results were favorable for investing in the new location, with a payback period of nearly four years. Finally, qualitative factors concerning the new location were explored through interviews, and reveal another perspective, but overall, the qualitative factors are in favor of the new location.

บทคัดย่อ

วัตถุประสงค์ของงานวิจัยฉบับนี้ จัดทำขึ้นเพื่อศึกษาและเสนอแนะทางเลือกของสถานที่ตั้งโรงงานผลิตปูนขาว (lime-burning) สำหรับการขยายธุรกิจ ซึ่งทำให้ลดต้นทุนด้านการขนส่งให้เหลือน้อยที่สุด โดยทั่วไป โรงงานในลักษณะนี้จะมีที่ตั้งอยู่ใกล้กับแหล่งวัตถุดิบ แต่อย่างไรก็ตาม สถานที่ตั้งปัจจุบันของโรงงานแห่งนี้ตั้งอยู่ห่างจากแหล่งวัตถุดิบ 20 กิโลเมตร และห่างจากลูกค้าโดยเฉลี่ย 200 กิโลเมตร

การเลือกตำแหน่งที่ตั้งของทรัพยากร (Facility location models) รวมถึงวิธีหาจุดศูนย์กลาง (Center of gravity method) และทฤษฎีของ แอลเฟรด เวเบอร์ ได้ถูกนำใช้เพื่อช่วยในการหาภาระระยะทางขนส่ง (load distance method) โดยทางเลือกที่ดีที่สุดได้ถูกเลือกนำมาใช้ ผลการศึกษาพบว่าสถานที่ตั้ง

*This is a much condensed version of Mr. Suphamphong's project report for the degree of MSc in supply chain management, awarded by Assumption University in January 2012. Much confidential data has been excised.

ที่ได้ถูกเลือกขึ้นใหม่สามารถช่วยประหยัดค่าขนส่งได้ถึงปีละ 5 ล้านบาทต่อปี นอกจากนี้ต้นทุนที่เพิ่มขึ้นจากการย้ายสถานที่ตั้งโรงงานได้ถูกคำนวณจากทั้งต้นทุนแปรผันและต้นทุนคงที่ การหามูลค่าปัจจุบันสุทธิ อัตราผลตอบแทนภายใน และระยะเวลาคืนทุน ถูกนำมาใช้ โดยผลทั้งหมดจากการศึกษาเป็นที่น่าพอใจสำหรับการลงทุนในสถานที่ตั้งแห่งใหม่ โดยมีระยะเวลาคืนทุน 4 ปี ท้ายที่สุดปัจจัยเชิงคุณภาพ ที่เกี่ยวข้องกับทำเลที่ตั้งใหม่ได้ถูกนำเสนอโดยการสัมภาษณ์ และแสดงมุมมองใหม่ขึ้น อย่างไรก็ตาม โดยรวมปัจจัยเชิงคุณภาพยังคงเอื้อและเป็นที่น่าพอใจสำหรับทำเลที่ตั้งใหม่ของโรงงาน

INTRODUCTION

Finding an optimal location is a major strategic concern for many firms, as it could control transportation cost and secure a competitive advantage. Being located in an optimal location is an important strategic decision in supply chain management. Choosing a new site requires high investment and it cannot then 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, if the facility location is not at the right place, excess cost would inevitable occur, mainly transportation and labour costs. This is especially the case for products in the category of heavy manufacturing and weight-losing (raw material weight is lost in the production process).

For a company to consider moving its facility, it has to clarify the problem with the present location. Can this problem be solved within the current location, or is a new location the answer? Often, managers do not like to challenge themselves by making a move, because of the risks. However this is a long-term threat which could force the firm out of the market.

Turning now to the company bacxkground, the Gypboard Company (a pseudonym for confidentiality) was founded nearly twenty tears ago and has three product lines, all facing increasing demand. Its fibreboards, for interior walls, are exported to Taiwan and Saudi Arabia. Another product, hard burned lime, is used in special types of concrete. Silica powder is used in the ceramic industry. The last two products are sold in Thailand, by this leading company All three production sites are located in a town in Eastern Thailand.

The annual demand for hard burned lime increases by 20%, and the company has reached its maximum production capacity. The company planned a capacity expansion in 2012, with a new lime kiln to be located next to the current facility. This could save cost by sharing facilities, equipment and workforce.

Burning limestone is categorized as a weight-losing heavy manufacturing industry. This industry is usually located next to the raw material source to achieve low cost of inbound transportation. The current plant location is 20 kilometers away from the raw material source and on average around 200 kilometers away from its customers.

Despite its proximity to its raw material source, the company incurs 500,000 baht/month for transportation. In the production process there is a 34% weight loss. 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, as price is the criterion for customers, and there is price competition between three big suppliers. Operating at low cost is essential to survival. Having a manufacturing location which minimizes transportation cost could be a strategic advantage. Therefore, should Gypboard Company expand its four new lime kilns at the current location, as management has suggested, or consider a new location?

REVIEW OF RELATED LITERATURE

SCM and Facility Location

Langevin and Riople (2005, p.40) showed that there is a clear link between facility location and Supply Chain management. They 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."*

The location of the supplier, manufacturer or customer, can change the whole supply-chain: a location change of one of them affects all parties. Selecting a facility location decision is a strategic decision, but also has many operational and tactical issues, such as the vehicle routing plan, inventory policies, warehouse capacity and layout. For example, an increase in distribution centers would result in higher inventory cost but usually better customer service.

Facility Location

Bumb (2002) gives an interesting overview of facility location. He lists four elements.

1. A set of positions where facilities could be built. For every location there must be information of the cost involved in building it.
2. A set of demand points (customers) which occupy geographical positions related to facilities location. Each demand point incurs different transportation costs.
3. A list of all conditions to be met by the built facilities and demand points.

4. A function that associates each set of possible facilities with the cost incurred if all the facilities in the set are opened, with demand points assigned so that all requirements are fulfilled. The objective is optimization.

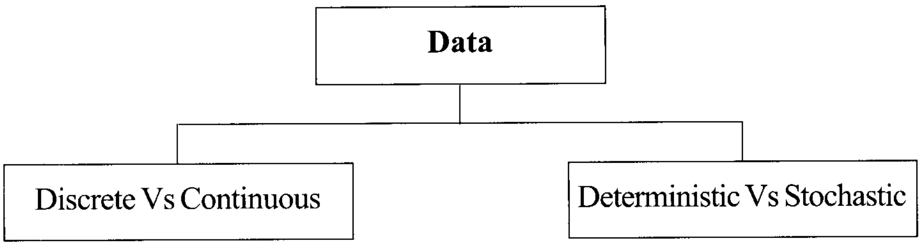
Mahadevan (2007) explained that the first decision is whether to build a new facility, expand on an existing site, or relocate to another site. Each choice has advantage and disadvantage. For example, an onsite expansion has the benefit of keeping people together, reducing construction time and costs,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

Type of Location Problem

Hamacher and Nickel (1998) 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, a few location problems 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 problems are called the K-Median problem.

Some basic characteristics of the data used in location problems are now introduced.

Figure 1: Types of Facility Location Problems

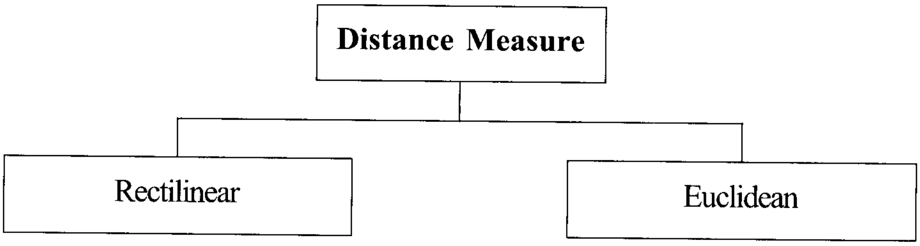


Owen (1999) explained the concept of discrete facility location problems. In these, the demand locations and facility locations are restricted. Otherwise, these location problems are called continuous facility location problems. Brandeau and Chiu (1989) explained the deterministic and stochastic problems. Deterministic facility locations are where all the data used in the calculation are exact. However if there are parameter values 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:

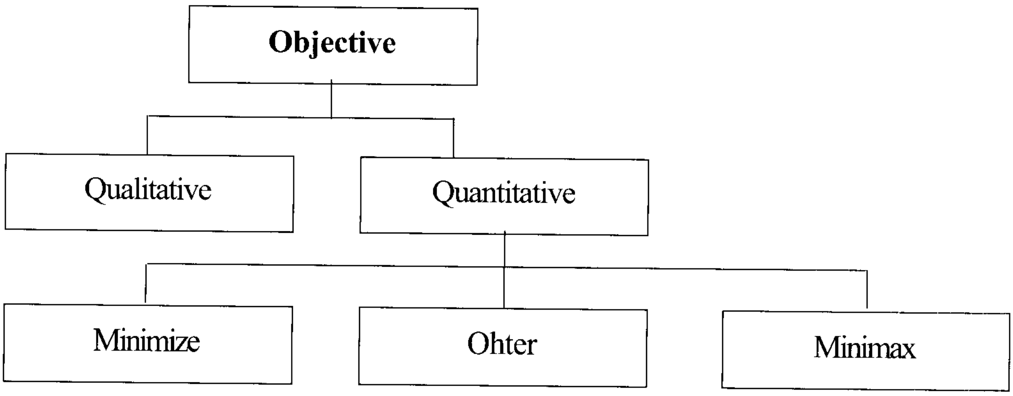
Distance measure between i and j: Rectilinear: |xi-xj| + |yi-yj|
Euclidean: [(xi-xj)2 + (yi-yj)2]0.5

Figure 2: Classification of Distance Metrics



The last category is the arrangement of objective functions. All the models in the literature that deal with facility location, are in two sub categories: Qualitative and Quantitative.

Figure 3: 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.

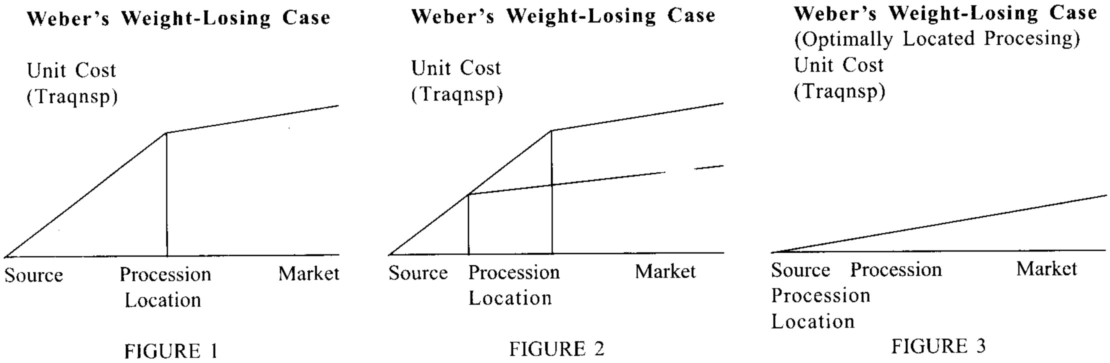
Most models are quantitative; considering transportation costs for both upstream and downstream transportation. Qualitative models claim that qualitative factors such as labor skills have a much higher impact in the long run than quantitative factors.

However many studies have agreed that selecting a facility location is a multi objective problem, and cannot be tackled by either the quantitative or the qualitative model alone. Some studies try to connect both. Vinh and Devinder (2005) developed a conceptual framework for a site selection, by combining both quantitative and qualitative factors in their decision making.

Historical Models

Weber (1868-1958) began modern location theories. He formulated 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: transportation, labor, and agglomeration (many companies in the same area can provide mutual assistance through shared talents, services, and facilities). In his Weight Losing case, 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.

Figure 4 : Weber's Weight Losing Model



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

In the above Figure, the processing plant is located between the source and the market. The increase of transportation cost to the left of the processing plant is the cost of transporting the raw material from its source. The rise in transportation cost to the right of the processing plant is the cost of transporting the final product. The line on the left of the processing plant has a much steeper slope than the one on the right.

Quantitative Location Models

There are many quantitative models for facility location. Barry and Chris (2001) emphasized the importance of choosing the appropriate theory, and that it is very important that the strategic goals of the company are aligned with the facility location.

Several quantitative facility location models will now be reviewed, beginning with the most common one, load distance

The load distance method is the most basic location model in operation research. (Russell & Taylor 2003). It is used to evaluate and compare different possible locations. It is a mathematical model focuses on distance and load between facilities. Distance can be actual mileage, or a straight line based on X ,Y coordinates. As an alternative, the time used to travel between facilities can be used instead of distance. There is a load distance formula

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

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

(xi, yi) = coordinates of existing facility

Another model is the Center of gravity theory, one of the most famous single facility location models (Bozarth & Handfield, 2006; Sahin & Sural, 2007). This model is used to locate a facility that is central to both demand and supply points. It 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:

$$X_c = \Sigma V_i X_i / \Sigma V_i \qquad (2.3)$$

$$Y_c = \Sigma V_i X_i / \Sigma V_i \qquad (2.4)$$

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 criticisms of this model. It does not consider the fixed cost involved in establishing a facility, and does not consider factors such as the availability of roads in selected locations. Therefore, this model is not effective for every case, and in some cases modifications have to be made.

Balinski (1964) is known as the founder of the fixed charge location theory. This model is better than the center of gravity method because it can assign several facility locations, and includes the facility cost factor. This model determines 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 points, so that the fixed cost of locating the facilities and the transportation costs are minimized. This model has two decision steps (Nozick, 1998):

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.
f_j fixed cost of locating a facility at site $j \in J$.
D_i annual demand at demand point $i \in I$.
c_{ij} cost per unit to ship from facility site $j \in J$ to demand point $i \in I$.

The decision variables are:

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

Subject to $\sum_{j \in J} Y_{ij} = 1 \quad A_j \in I.$ (2.6)

$Y_{ij} \; x_j \quad A_i \in I$ and I (2.7)

$x_i \in \{0, 1\} \quad A_j \in J$ (2.8)

$Y_{ij} \in \{0, 1\} \quad A_i \in I$ and $A_j \in J$ (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.

Moving on, traditional 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) stated the need for a combination of both quantitative and qualitative methods.

The most popular qualitative facility location method is the weight factor rating model (Wisner, Leong and Tan, 2005; Russell and Taylor, 2003). The steps in this model are all very similar. First, 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.

Modern location models have combined the AHP decision model (which is a structured technique for organizing and analyzing decisions)with the factor rating model, which makes the latter model more accurate.

Many researchers investigated the qualitative aspect of facility location. Miller (1993) stressed the importance of these factors, arguing that they often outweigh the quantitative model results. The factor 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 emphasized.

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: Location of major market; Location of materials and/or service; Availability of labor; and Suitable transportation links.

MacCormack, Newmann, and Rosenfield (1994) said that qualitative facility location received only limited exposure in the strategic planning literature, as there was too much reliance on quantitative factors such as transportation and labor costs. Location decisions based primary on cost factors underestimates the importance of qualitative factors which could provide long term advantages.

Related Literature

There are now many advanced models that help organizations to locate their facilities. Many of the quantitative mathematical models focus only on customer and supplier transportation cost, and fail to include inventory cost which is directly linked to the facility location. Many studies have recognized the close connection between the management of facility location, inventory, and transportation policy (Perl & Sirisoponsilp, 1989).

Vaidyanathan (1998) developed a model (FLITNET) to design an optimal distribution network, which analyzes the interdependence of the facility location, inventory, and distribution. This model would produce an optimal solution which considers the trade offs between location, transportation, and inventory.

There are many other theories which link the location of a facility to other factors, such as customer service, and JIT. Da (2010) studied how economies of scale impact the decision of facility location. He demonstrated in a case study, that significant cost could be saved by involving the economies of scale factor in the facility location decision.

Meloa, Nickel, and Saldanha (2009), have summarized many studies. 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 which combined transportation modes with facility location, and 7 which combined procurement with facility location. There are 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.

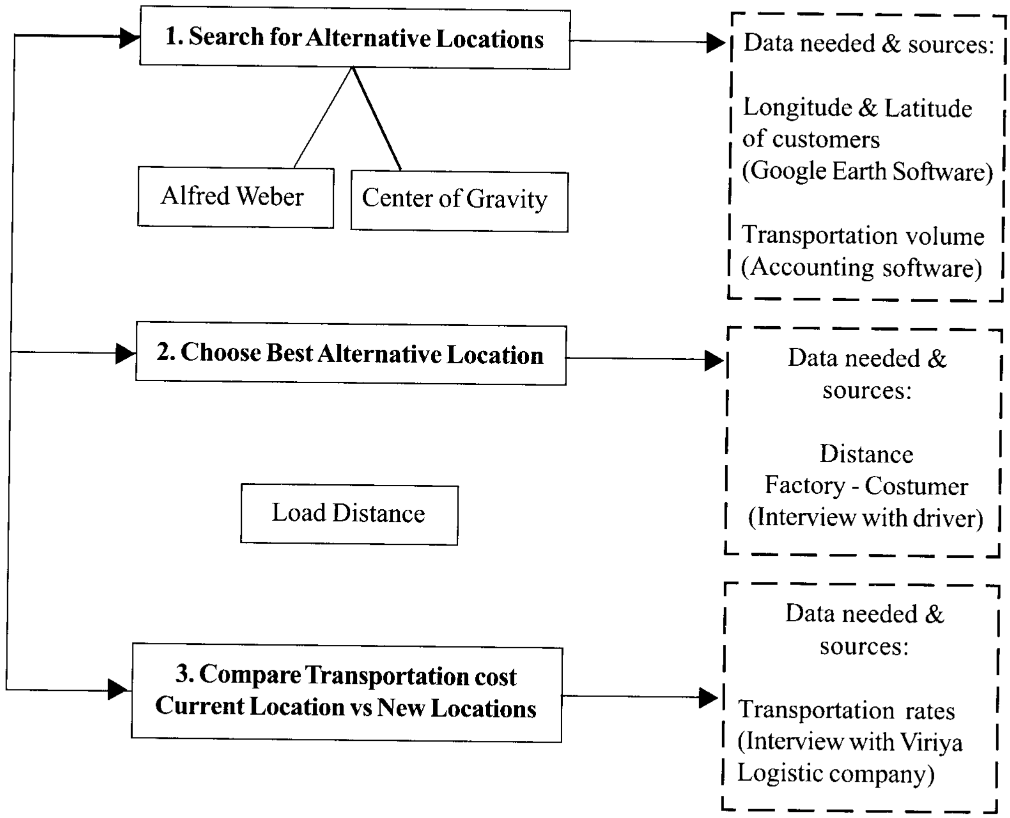
METHODOLOGY

The quantitative approach is applied to the problem. Reasonable alternative locations will be identified with 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 will be compared to the new location. The methodology is illustrated in the Figure below.

Data Collection

Longitude and Latitudes data were acquired by taking the location map of the supplier/ customers and positioning them in Google Earth software. The X and Y coordinates were identified through overlaying an X/Y coordinate system over the map. Next, the transportation volume was extracted from the accounting software. The transportation volume between the factory and each customer was taken from the average of the last six-month history volume of each customer. The distance between the factory and each customer was obtained through interviews with the truck driver at each location: it is actual road distance data. Finally the transportation cost was gathered through interviews with Fibreboard Company's transportation company.

Figure 5: Structure of Methodology



First, some alternative locations had to be identified, using the center of gravity method, which finds a location that minimizes transportation cost between inbound and outbound, treating transportation cost as a linear function of distance and quantity. The steps were:

1. The Longitude and Latitude of the current supplier and customers were collected.
2. The Locations of both supplier and customers were marked into the map according to their Longitude and Latitude values.
3. A coordinate system was overlaid on the map to determine the relative locations. The locations of the firm's existing customers and supplier were then converted into X and Y coordinates.
4. The average shipping volume for each location was approximated (data being obtained from an interview with the sales personnel of the Gypboard Company).
5. The data for the center of gravity calculation was prepared.

Since the quantity shipped from and to each destination is not equal, a weighted average was applied, where the weights is the quantities to be shipped. The X and Y coordinates for the center of gravity were obtained by summing the weighted coordinates and dividing that by the monthly shipped volume. Following is the formula:

$$X_c = \Sigma \text{Vi Xi}/\Sigma V \qquad (3.1)$$
$$Y_c = \Sigma \text{Vi Yi}/\Sigma \text{Vi} \qquad (3.2)$$

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 = 19.59
Yc = 319,050 / 17,500 = 18.23

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

Weber's Theory
Weber's Weight Losing theory has been taken as an alternative in locating the proposed expansion, because:
1. Weight loss of 35% in the production of Lime (Due to the emission of carbon dioxide)
2. High inbound transportation cost.
3. Cheap land price at raw material site. Weber's theory is that the optimal location should be at the raw material site.

After a field study at the raw material source, plenty of land was seen to be available 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.

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 real actual distance. Therefore the actual distance was collected.
The steps involved in the load distance calculation were:
1. Collecting distance data between: Firm-Customers, and Firm-Supplier
2. Estimating the load of Customers and Supplier.

3. Calculating Load distance

An approximation of sales and purchasing quantity was made, from an interview with the sales personnel of Gypboard Company. To make the calculation simpler, the customer demand per month was transferred into load factors, by dividing all the demand quantities by 1,000. Finally the distance of each location is multiplied by the load factor; the location which has the minimum load distance is the superior location.

The Weber location method has the minimum Load-distance (1250). Therefore, according to the load distance method, the superior location is the Weber location.

The total transportation cost of the current location was calculated and compared to the best alternative location. Transportation cost included inbound and outbound coasts, between:
1. Raw material source - Current Location - Customers
2. Raw material source - Weber Location - Customers

Finally the total transportation costs of the new location and the current location are compared. The result was that the new location would be 20% less than the old, an annual saving of US$170,000.

RESULT AND ANALYSIS

The favourable transportation cost result, a saving of 20%, has to be considered alongsidewith some other financial details, good and bad.

Expense
There is some additional investment required for Gypboard Company to expand at the new location. The fixed investment cost and variable cost were obtained from the project engineers, vehicle prices from the purchasing department, and building costs from Thai Governmental cost estimates of 2011. The land price was acquired through an onsite visit. The salary cost was obtained from the human resource department.

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)

$$NPV = \sum^{T} \frac{Nt}{(1+i)^t} \qquad (4.1)$$

$$NPV = 3,257,572$$

The NPV value is positive; therefore Gypboard Company should invest in the new location.

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 formula in Excel was applied, and the IRR value obtained was 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.

Payback period Calculation

The payback period determines the amount of time it takes to break even on investing in the new location. 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)

The Payback period calculation result is 3 years and 7 months

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 Gypboard Company. For confidentiality, only the positive aspects are examined here.

Produce Lime at Low cost: Due to the low inbound transportation cost, the production cost of 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: The company. 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.

One negative aspect is mentioned here. There is a 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.

It is difficult 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 Gypboard Company. can successfully run their operation at the new site under the constraint of the negative factors.

CONCLUSION AND LIMITATIONS

This study found a location which minimizes the total transportation cost for Gypboard Company: a location next to the raw material source. The total transportation cost of the new location has been calculated and compared to the current location, and would mean a reduction of 20% of the present cost. The financial feasibility for investing into the new location has been calculated, and is positive. All the figures support investment in the new location.

However, as in any research, there are Limitations and Recommendations. Due to the broad scope of this study and time limitation, the optimal location in this study derived from only three facility location models. There are many other relevant models which could be used, such as the Mixed Integer Programming model.

The calculations 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 cost is the most important factor. 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.

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

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 who might become future customers. Further studies could use models of different groups of customers and observe whether and how the optimal location would change.

BIBLIOGRAPHY

Balinski, M. L. (1964). On finding integer solutions to linear programs. Unpublished Master Thesis, Princeton University, New Jersey.

Ballou, R.H. (2004). *Business Logistics/ Supply chain management: Planning, Organizing and Controlling the Supply chain*. New Jersey: Pearson/Prentice Hall Inc. 5th edition.

Barry, B., & Chris, S. (2001). The Location and site selection decision process: Meeting the strategic and tactical needs of the users of corporate real estate. *Journal of Corporate Real Estate* 20(5), 65-66.

Birnberg, J., & Love, R.F. (1994). A location problem with economies of scale. *Studies in Locational Analysis*, 7, 9-19.

Bozarth, C.C., & Handfield, R.B. (2006). *Introduction to Operations and Supply Chain Management*. New Jersey: Pearson/Prentice Hall Inc. 1st edition.

Brandeau, M.L. & Chiu, S.S. (1989), An overview of representative problems in location research, *Management Science*, 7, 9-10.

Bumb, A. (2002). *Approximation Algorithms for Facility Location Problems*. (Ph.D. Dissertation). Retrieved July 29, 2010 from: http://www.tup.utwente.nl/tupress/catalogue/book/index.jsp?isbn=9036517877.

Chen, C.W., & Sha, D.Y. (2001). A new approach to the multiple objective facility layout problem. *Journal of Integrated Manufacturing Systems*, 15(7), 59-66.

Da, L. (2010). *Facility location with economies of scale and congestion*. Unpublished Master Thesis, University of Waterloo, Ontario, Canada.

Hamacher, H.W., & Nickel, S. (1998). Classification of location problems. *Location Science*, 229(6), 242.

Helander, M., & Emanuel, M. (1997). Facility Location and Reliable Route Planning in Hazardous Material Transportation. *Transportation Science*, 31(3), 216-226.

Langevin, A., & Riople, Diana (2005). *Logistics Systems: Design and Optimization*. New York: Springer.

MacCormack, A.D., Newmann, L.J., & Rosenfield, D.B. (1994). The new dynamics of global manufacturing site location. *Sloan Management Review*, 35(4), 69-80.

Mahadevan, V. (2007). *Operations Management: Theory & Practice*. New Delhi: Pearson Education.

Meloa. T., Nickelbach, F., & Saldanha G. (2009). An LP-rounding heuristic to solve a multi-period facility relocation problem. *Berichte des Fraunhofer*, Nr. 168, 9-10.

Miller, T. (1993). Learning about facility location models. *Journal of Distribution*, 92(5), 47-49.

Nozick, L.K., & Turnquist M.A. (1998). Integrating inventory impacts into a fixed charge model for locating distribution centers. *Transportation Research*, 34(4), 173-186.

Owen, S.H. (1999). *Scenario Planning Approaches to Facility Location: Models and Solution Methods*, (Ph.D. Dissertation), Northwestern University.

Retrieved on July 9, 2010, from http://citeseerx.ist.psu.edu/viewdoc/download?doi= 0.1.1.70. 1921.

Perl, J., & Sirisiponsilp, S. (1980). Distribution networks: Facility location, transportation and inventor. *International Journal of Physical Distribution & Materials Management*, 18, 18-26.

Russell, R. S., & Taylor, B. W. (2003). *Operations management*. New Jersey: Prentice Hall Inc. 4th edition.

Sahin, G., & Süral, H. (2007). A review of hierarchical facility location models. *Computers & Operations Research*, 34, 2310-2331.

Scott, P. (1989). Location means business. *Cma magazine*, 63 (2), 10-15.

Vaidyanathan, J. (1998). Transportation, facility location and inventory issues in distribution network design: An investigation. *International Journal of Operations & Production Management*, 18(5), 471-494.

Vinh V.T., & Devinder G. (2005). Selecting the location of distribution centre in logistics operations: A conceptual framework and case study. *Asia Pacific Journal of Marketing and Logistics*, 17(3), 3-24.

Wisner, J.D., Leong G.L., & Tan, K.C. (2005). *Principles of Supply Chain Management: A Balanced Approach*. Ohio: Thomson Business and Professional Publishing.