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Research on factors affecting Thai manufacturer deal with supply chain disruption toward decentralization

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RESEARCH ON FACTORS AFFECTING THAI MANUFACTURER DEAL WITH SUPPLY CHAIN DISRUPTION TOWARD DECENTRALIZATION

BY

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation: **Research on Factors Affecting Thai Manufacturer Deal with Supply Chain Disruption toward Decentralization**

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Disruption is a random, unpredictable and unavoidable risk in the supply chain that cause damage for the whole supply chain, even the disruption is occurred at only small node of the supply chain. The higher complexities of the supply chain, the greater effect that feasibly affect and caused damage to the whole stakeholders along that particular supply chain.

While the practice of just-in-time and lean manufacturing are widely accepted in order to minimize excessed wasted and cost, the vulnerable is higher vulnerable is a consequent of these practices. Moreover, centralized network that has been applied for convenience and cost reduction is diminished the flexibility of the network flow.

This research paper illustrates the impact of these practices due to the disruption in the supply chain by selected Thai SMEs manufacturer. The company ignores the important of the systematic inventory as well as the distribution. This research is find out the problem that affected by disruption to the company. Then, the revision of inventory policy as safety stock has been revised, while decentralized concept has been proposed with applied AHP model in this research.

The conclusion of the research has been shown the alternative that the company selected the best result of level of safety stock and the best alternative warehouse for decentralized.

KEY WORDS: Disruption in supply chain, safety stock, decentralization, AHP

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CDC	Central Distribution Center
DC	Distribution Center
ICD	Inland Container Depot
JIT	Just in time
LCL	Less than container load
LT	Lead time
MCDM	Multi criteria decision making
OEM	Original equipment manufacturer
RDC	Regional Distribution Center
S1	Supplier 1
S2	Supplier 2
S3	Supplier 3
S4	Supplier 4
S5	Supplier 5
S6	Supplier 6
SCOR	Supply Chain Operations Reference
SMEs	Small – Medium Enterprise
SS	Safety Stock
TEU	Twenty feet equivalent units

Chapter 1 Introduction

1.1 Introduction

(Johnson, Supply Chain Management: Technology, Globalization, and Policy at a Crossroads, 2006) As their global production systems become increasingly complex and integrated, firms need sophisticated models to allocate production throughout world. Due to sophisticated global supply chain, outsourcing practices are continuously grown cross all continents; various companies outsource production into cheaper places as labor cost. (CFO Research Services in Collaboration with FM Global, 2009) Intense business competition in recent years has led many companies to reduce operating costs by sourcing raw materials and production inputs from overseas. Therefore, logistics is play a critical role in transferring each component from various factories in different country to the assembly line in one country before transferring finished product to each distribution center and market in various countries.

Within current few decades, these complexities of supply chains have been critically considered. The higher complexity, the higher sensitivity of risk that can be disrupted the supply chain. Small error at one node can lead to disruption in the whole global supply chain. Disruptions in supply chain consequently lead to damage and loss in term of economic and finance. Therefore, supply chain risk management has been currently more concerned.

Various major incidents have been illustrated that caused disruption in supply chain, besides world economic crisis that cause uncertain demand risk. For example, terrorism as 9-11 or natural disaster; major earth quake in California, Hurricane Katrina, Hurricane Rita, Tsunami in Japan and recently flood in Thailand.

Flood in Thailand is obviously damaged and disrupted global supply chains in various sectors, especially industrial sectors since flood occupied Ayutthaya province and followed by Pathum Thanee province as well as Bangkok. According to the flood, five industrial estates in Ayutthaya province and two industrial estates in Pathum Thanee were flood, including Bang-Pa-in, Hi-Tech, Factory Land, Rojana, Saha Rattana Nakorn, as well as Nava Nakorn and Bang Kadi. (The Federation of Thai Industries, 2011) 838 factories in these seven industrial estates are totally sunk with 30% of automotive sector and 26% of electronics sector and other sectors, including rice mill, food & beverage and so on. Others 9,021 factories are impacted due to lack of spare part and/or raw material accessibility. Therefore, these impacted factories are force to slow down or temporarily terminate their production line. This incident impacts the whole supply chain not only industrial sector.

Logistics sector has been consequently impacted by slow down and terminated producing by around 10,000 factories which were impacted by the flood. Therefore, import and export activities from both big manufactories and SMEs have been inevitably decelerated as well as terminated. (Logistics Digest, 2011) Mr. Vallop Vitanakorn, Vice President, Thai National Shippers ‘Council, mentions that most of Thai exporters is Small – Medium Enterprises (SMEs) which delivered pattern is less than container load (LCL). If shippers are not able to deliver finished goods to Inland Container Depot (ICD), the container is not been fulfilled. The container is not able to be loaded on board. Consequently shipping line cells are not fulfilled.

Logistics transactions significantly declined due to terminated production and inaccessibility of various routes. These incidents lead to loss income in all logistics providers; port, inland logistics, warehouse and distributions. These direct and indirect impacts to domestic manufacturing and logistic system have severely damaged and disrupted global supply chain especially in automotive and electronics industry sectors.

From this incident various recommendations are arisen that involving with reengineering the whole supply chain activities practices and pattern in term of Just-in-Time system, lean system, inventory level, and distributed network. As manufacturer companies, the suitable strategic planning to deal with disruption in supply chain as well as respond to the market reaction, the critical factors of company has to be identified. SSS-Thanee Food Co., Ltd is one of Thai manufacturer that impacted due to the flood event. The company realized and revised existing production and distribution practices in order to deal with the risk in supply chains.

1.2 Objective of the Study

The objective of the study is to identify the factors that affect decision making of Thai SMEs manufacturer to diversify risk in the supply chain through decentralization. The factor that company really concern involving with company current situation, market situation as well as the potential aspect that the company is able to develop proactive supply chain risk management plan, in applying decentralization network.

1.3 Limitations of the Study

a) The research will focus only on Thai SMEs manufacturer, SSS-Thanee Food Co, Ltd that impact by the disruption in the supply chain, flood in Thailand.
b) The research focus only on the character and impact of the disruption toward export product, exclude domestics sales of the company.
c) Due to the condition of the company, financial issue is not taken into this research.

1.4 Structure of the Dissertation

Chapter 1 INTRODUCTION

This dissertation chapter initially introduces background of the study, objective of the study and the limitation of this research.

Chapter 2 LITERATURES REVIEW & CONCEPTUAL FRAMEWORK

This chapter aims to overview several relevant research papers in order to carry out a comprehension of the supply chain disruption management as well as the related reported and analysis of the flood situation in Thailand.

Chapter 3 RESEARCH METHODOLOGY

This chapter presents, including detail explanation of methodology which will be applied in this dissertation.

Chapter 4 DATA COLLECTION

This chapter presents the collected data in both general description of the research object of SSS-Thanee Food., Ltd, and required data in this research which consist of the data about existing inventory system of the company as well as the distribution network pattern.

Chapter 5 Analysis

This chapter presents the analysis of the data collection focusing on redesign of inventory management, as safety stock level and the applicant of decentralization concept for increasing flexibility of the network flow.

Chapter 6 CONCLUSION & RECOMMENDATION

The chapter present brief conclusion from the research and provided some recommendation

Chapter 2 Literature review and Conceptual Framework

2.1 Introduction

This chapter will discuss about the related literature that study about supply chain risk management. Most of them indicated that the causes of fragile and vulnerable supply chain lead to disruption in the supply chain are derived from operations and disruption risks. However, Both operations and disruption risks could seriously disrupt and delay materials, information, and cash flow, which in the end could damage sales, increase costs, or both (Pujawan & Geraldin, House of Risk: a model for proactive supply chain risk management, 2009) quoted Chopra and Sodhi, 2004.

2.2 The practice of pull system and inventory level impact to disruption in supply chain

Various researchers have questioned about whether pull system or "Just-in-Time system" is really the best practice or not in order to confront with the disruption in supply chain. Pull system of "Just-in-Time" is widely practices in lean production line. (Lumsden, Principles for material control, 2012) Pull system has used to provide down line customers in the production process with what they want, when they want it, and in the amount they want. Material replenishment initiated by consumption is the basic principle of just-in-time. This system use to minimize work in process and warehousing of inventory by stock small amounts of each product and frequently restocking based on what the customer actually takes away.

Even zero stock or small amounts of inventory stock practices have been widely accepted that could diminish waste inventory, increase inventory turnover rate and lower inventory holding cost as best practices, various researchers in a last few year have criticized this system that is very high sensibility and caused to supply chain disruption. (Pochard, 2003) Modern supply chains are very complex, and recent lean practices have resulted in these networks becoming more vulnerable. (V.S.Srividhya

& Jayaraman, 2007) Supply risk factors are further amplified when considered in the context of cost efficiency strategies that have been adopted by several manufacturing companies. Strategies such as consolidation of supplier base, lean manufacturing and JIT pose serious threats in case of disruption to normal routine. Making systems lean is a risk due to the fact that a local disruption or event can cause the entire supply chain to be at risk. (The supply chain council risk research team, 2008) One of the key factors contributing to disrupting supply chains is the focus on lean supply chain in academia and industry during the 90s. Zero-inventory and just-in-time movement of goods became the dominant model that increased the sensitivity of supply chains. (CFO Research Services in Collaboration with FM Global, 2009) Just-in-time inventory and lean manufacturing practices-business practices that tend to increase exposure to supply chain risk. (Kleingdorfer & Saad, 2005) Extreme leanness and efficiency may result in increasing the level of vulnerability, at both the individual firm level and across the supply chain.

2.3 Centralization and Decentralization in diversified risk due to disruption in supply chain

2.3.1 Centralization

Centralization is mostly used in to optimal the cost of holding inventory cost and reduce cost of assets. (Lumsden, Distribution System, 2012) The fact that reduce capital costs can be achieved by using centralized storages, has led to many companies centralizing their storages.

However, various researchers have studied and pointed out that centralization could reduce capital cost only there are no any others disruption or error occurred during the supply chain process. (Mason & Gruebele, 2001) The use of the hub minimizes risk and maximizes returns to all those who use the hub, since a priori knowledge of risk cannot exist in a logistics environment. (Schmitt, Snydeer, & Shen, 2008) The risk pooling effect occurs when inventory is held at a central location, which allows the demand variance at each retailer to be combined, resulting in a lower expected cost.

Moreover, (Schmitt, Snydeer, & Shen, 2008) show the summary of numerical comparison poof by One-Warehouse Multiple-Retailer (OWMR) system, that the risk-pooling effect is more pronounced when disruptions are less frequent and shorter, or when demand is more variable. (Seyhan, Snyder, & Shen, 2011) Risk pooling is obtained from consolidating the safety stocks of several retailers at a centralized distribution center (DC), making use of the concavity of the cost function. As a result fewer inventories are held and thus a smaller cost is incurred in a centralized setting compared to a decentralized one, when the retailer demands are not perfectly correlated.

2.3.2 Decentralization

Various studies have proved that decentralization is more flexible and better respond to the supply chain risk due to disruption in the supply chain. (Schmitt, Snydeer, & Shen, 2008) The risk diversification effect occurs when inventory is held at a decentralized set of locations, which allows the impact of each disruption to be reduced, resulting in a lower cost variance. For a risk-averse firm, the decentralized system is typically the optimal inventory design. (Seyhan, Snyder, & Shen, 2011) Risk diversification is obtained by allocating a retailer to backup DC's along with a base DC. This diversification of supply risk increases reliability and favor decentralization.

(The supply chain council risk research team, 2008) Using SCOR methodology to measure these two systems, centralization and decentralization that act in a coordinating function by aligning the SCOR risk activities with the overall business risks management program, decentralization was finally selected because it was more aligned too the current SCOR model philosophy and function.

From these two networks, decentralization is strongly recommended in order to deal with the disruption in the supply chain. Studies have shown that decentralized distribution center play as risk diversification in the supply chain management.

2.4 The Challenge of dealing with Supply Chain Disruption and Risk Management

(Cheong, 2005) Logistics network design is an important strategic decision that companies must make to ensure that required raw materials and components can be distributed efficiently from their suppliers to their manufacturing plants and warehouses, and the final products to their customers. It is concerned with the determination of the number and location of warehouses and production plants, allocation of customer demand points to warehouses, and allocation of warehouses to production plants.

(Cognizant Supply Chain Management Team) Mentioned Dr. Lee's research that identifies certain companies that appear to have established "bullet-proof" strategies relative to their supply chains, thus leading them to achieve a sustained competitive advantage. These companies' supply chains are not just low-cost and high-speed, but, most importantly, they also have the characteristics of "Triple-A Supply Chain" , include; Agility, Adaptability, and Alignment.

(Handfield, Blackhurst, Craighead, & Elkins, 2011) Three critical components of supply chain disruption management, or supply chain triad, including (1) the ability to discover that a disruption has occurred, (2) the ability to effectively recover from the disruption and (3) supply chain redesign strategies for resilience.

The issues of disruption in supply chains have been attracted in these last few years. Because of complexity of the global network, any small disruption will lead to the great impact to the total global supply chains.

2.5 The Cause and Respond of High Disruption Effect in Supply Chains from Flood in Thailand

Due to the recent flood in Thailand, huge economic damage is reported not only affect domestic loss but also impact to the global economic due to disruption in the supply chain. Various comments from academic and logistics sector about the cause of huge impact and suggest some solution for the logistics sector to be aware and more concerned about the supply chain disruption.

The impact of flood has both direct and indirect for domestic industrial sector (The Federation of Thai Industries, 2011) 838 factories in these seven industrial estates are totally sunk with 30% of automotive sector and 26% of electronics sector and other sectors, including rice mill, food & beverage and so on. Others 9,021 factories are impacted due to lack of spare part and/or raw material accessibility. Therefore, these impacted factories are force to slow down or terminate their production line. As seen from this report, numbers of indirect impact generate huge loss than direct impact from flood almost 11 times.

(Thai Post News, 2011) According to Mr. Siriwat Kajornprasart, Deputy Minister of Commerce, manufactured activities for export have severely declined due to flood. Major declined of exported product are industrial products that are impacted and declined by the flood: 54.7% in Automotive, 47.4% in electronics, 42.5% in toys, 21.9% in electronic appliances, 10.8% in jewelry, 16.8% in goal, and 10.3% in furniture and tools.

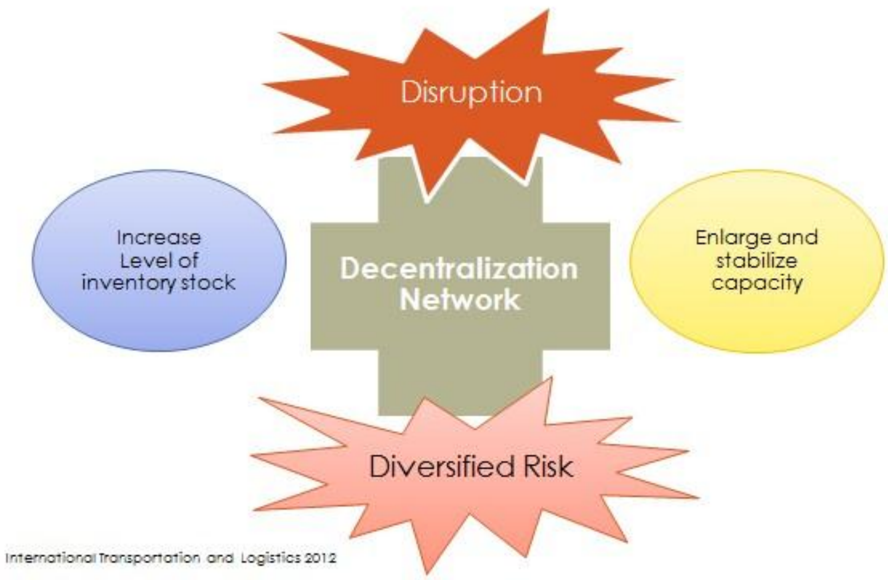
The causes of these losses have been commented by various academic and logistics sectors. (Bhanomyong, 2012) Industrial sector of Thailand is mostly centralized at the Central of Thailand. Therefore, the damage of flood has greatly affected to this sector for example, five industrial estates in Ayutthaya. This comment is also supported by various key person in academic and logistics sector (Logistics Digest, 2011) Mr. Ananworapol, advisor, Bangkok Shipowners and Agents Association (BSAA) diversification in the supply chain must be done. Right now majority of distribution centers are located in Central of Thailand where directly affected by the flood. Therefore, during flood crisis, all logistics activities are not able to process due to inaccessibility to the distribution center. As well as Mr. Paiboon Ponsuwanna, President, Thai National Shippers' Council mentioned that the practices of Just-in-Time create low inventory level practices disrupt manufacturing and supply chain due to lack of raw material in the inventory because raw material are not able to be delivered to the factories due to inaccessibility.

Moreover, some suggestion is arisen to reengineering Thai logistics system in order to deal with the disruption in supply chains. (Osathanukro, 2011) 1. Design network route as contingency plan in order to distribute product to the customer during the crisis 2. Apply flexibility (agile) logistics system including redesign production process and stock keeping and also redesign how to keep product 3. Inventory safety stock 4 reconsider about centralization (CDC) to Regional distribution center (RDC) or apply hub and spoke system.

However, the reaction of industrial sectors has mentioned (Manager News Online, 2011) Various manufacturers plan to extend or move their production line and warehouse to non-flood area, especially on north east of Thailand in order to diversify their risk caused of disruption in their supply chain.

2.6 Conceptual Framework

According to literature review, most of the studies mention the framework of diversifies risk in the supply chain. The covariance and correlation coefficient of disruption risk with different distribution model and inventory stock level have mentioned in plenty of study. Therefore, the factors that really concern for Thai SMEs manufacture in order to redesign its system for preventive strategic plan has been developed in this research. In order to mitigate risk of supply chain disruption, increase inventory stock has been concerned and this will lead to decentralized distribution in this research. Analytical Hierarchical Process model (AHP) is selected to find out the critical factors of Thai SMEs manufacturer concerned before making decision by interviewing to collect information.



Chapter 3 Research Methodology

The methodology of this research will be discussed in this chapter, which is basically divided into two parts. First is calculating level of safety stock in order to deal with the uncertainty of the demand in both raw materials and finished goods. Second is applied Analytical Hierarchy Process (AHP) model to solve the problem with various criterions due to decentralization.

3.1 Inventory Safety Stock Management

3.1.1 Safety Stock

Safety stock (SS) is an extra stock that is maintained to mitigate risk of shortfall in both raw material and finished goods. It has been concerned due to vulnerability of the supply chains in order to make sure that disruption and variations in demands and deliveries do not cause shortages, delivery readiness is required in uncertain surroundings.

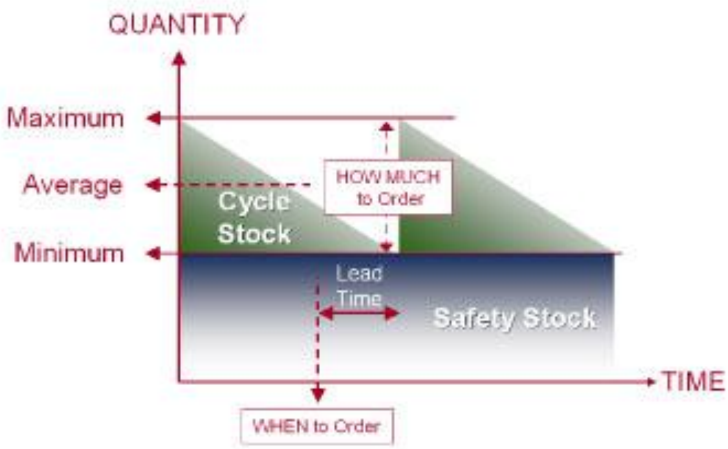


Figure 1: The safety stock as a function of variation of demand during the lead time
Source: http://www.safetystockcalculator.com (Unknown)

(Luthra & Roshan, 2011) Traditionally, inventory management experts have calculated a fixed economic order quantity (EOQ) that minimizes the cost of ordering and keeping stock. The reorder point is calculated as the stock level required to meet the demand for finished product and raw material, taking into account the time required for supply replenishment, called lead time, after the order has been made. However, there is always an error in forecasting demand and predicting lead time to inventory stock-out and an inability to meet customer demand. This can have an adverse effect on customer loyalty. This is why companies guard against this uncertainty by maintaining extra inventory, traditionally referred to as safety stock.

(Lumsden, The fucntion of the safety stock, 2011) The inventory should cover the demand for the entire batch cycle. This mean that the inventory along with the normal demand (D), which is satisfied by the cycle stock, has to be able to handle deviations from the normal demand, which the safety stock (SS) manages. This inventory should be large enough to avoid stock out situations during the lead-time (LT) for unexpectedly high outgoing deliveries, long lead-times for in deliveries, long transportation times and long deliver times.

$$SS = Z * \sigma D * \sqrt{LT}$$

When:

SS	=	Safety Stock
Z	=	Service factor
σD	=	Standard Deviation of Demand
LT	=	Lead Time

However, demand uncertainty is not only one factor that is considered in calculated level of safety stock; Lead time of shipment is also critical factor that is uncertainty (Atkinson, 2005) Inventory management is not to run out along with uncertainties in demand and supplier lead time. Then standard deviation of lead time is involved in the calculation. It is very important to track how long shipments take from suppliers.

$$SS = Z * \sqrt{\overline{LT} * \sigma_d^2 + \overline{D} * \sigma_{LT}^2}$$

When:

SS	=	Safety Stock
Z	=	Service factor
$\overline{LT}$	=	Average lead time
σ_d	=	Standard deviation of demand
$\overline{D}$	=	Average demand
σ_{LT}	=	Standard deviation of lead time

In order to calculate standard deviation in both demand and lead time, this research will use excel sheet with the function of STDEV.

3.1.2 Service Level

The size of safety stock is determined by the preferred service level. (Piasecki, 2012) Service level is a desired service level expressed as percentage. (Lumsden, Service Level, 2011) A progressive larger safety stock is required to reach a higher service level or possibility to satisfy orders. An increase of the service level with one percent involves a far higher increase of the stock level than the equivalent increase for a lower service level.

Safety factor is a number that is connected to the shape of the normal distribution. It is only connected to the percentage of the demand that is above the safety stock. (Piasecki, 2012) Service factors use as a multiplier with the Standard Deviation to calculate a specific quantity to meet the specified service level.

Table 1: The interrelation between the safety factors and service levels

Service Level	Service Factor	Service Level	Service Factor
50.00%	0.00	90.00%	1.28
55.00%	0.13	91.00%	1.34
60.00%	0.25	92.00%	1.41
65.00%	0.39	93.00%	1.48
70.00%	0.52	94.00%	1.55
75.00%	0.67	95.00%	1.64
80.00%	0.84	96.00%	1.75
81.00%	0.88	97.00%	1.88
82.00%	0.92	98.00%	2.05
83.00%	0.95	99.00%	2.33
84.00%	0.99	99.50%	2.58
85.00%	1.04	99.60%	2.65
86.00%	1.08	99.70%	2.75
87.00%	1.13	99.80%	2.88
88.00%	1.17	99.90%	3.09
89.00%	1.23	99.99%	3.72

Source: www.inventoryops.com

3.2 Analytic Hierarchy Process in making decision of decentralization

Making decision is an unavoidable part of daily life with consciously and unconsciously in order to meet highly satisfies of many need and get the greatest advantage of all alternatives and criterion.

Plenty of factors are caused of complexity in making decision. The more factors, the higher complexity obviously create problem to the people who require making a decision. Multiple-objective is caused confusion and dilemma when a lot of factors are concerned. Too much information is lead confusion and misses the initial goal that causes a real problem to the decision maker.

High expectation and pressure is placed and relied on decision maker, especially when the objective of making decision is to invest in some critical and value project. When invest in the project, various factors and information have been carefully considered and examined before making any judgment because it is not able to retrieve any single loss from failure due to mistaken decision making. Mathematic and qualitative research method has been applied for conclusive result. The Analytic Hierarchy Process (AHP) is introduced in various strategic decisions making situation.

(Winston & Albright, 1997) Thomas Saaty's Analytic Hierarchy Process (AHP) provides a powerful tool that can be used to make decisions in situations where multiple objectives are present. (J.Barker, 2010) AHP is a multi-criteria decision making (MCDM) method that provides a quantitative evaluation for decisions with both qualitative and quantitative decision factors. (Jablonsky, 2005) The Analytic Hierarchy Process (AHP) is a powerful tool for analysis of complex decision problems. The AHP organizes the decision problem as a hierarchical structure containing always several levels. The first (topmost) level defines a main goal of the decision problem and the last (lowest) level describes usually the decision alternatives of scenarios. The levels between the first and the last level can contain secondary goals, criteria and sub criteria of the decision problem. The number of the levels is not limited, but in the typical case it does not exceed four or five.

According to apply AHP model, the process will be described in the following steps:

3.2.1 Indicated factors of AHP model

In order to apply the model for making decision with multi-objective, the goal and specified requirement must be clearly identified. All criterion and factors must be decomposed as well as categorized sub factors into the structure. Then arrange them in hierarchy

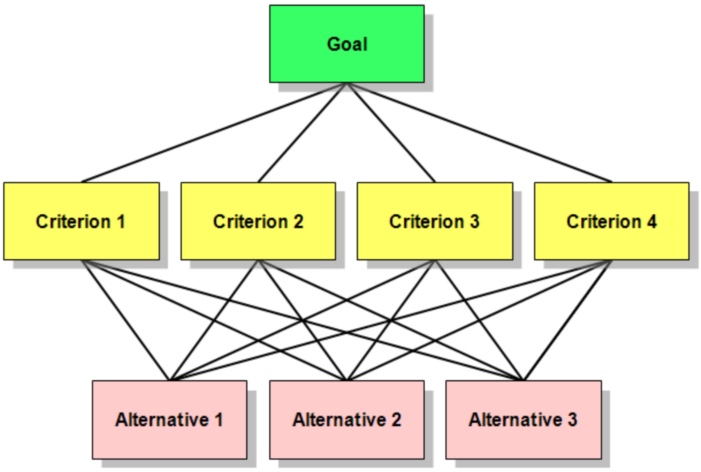


Figure 2: Analytic hierarchy structure model

3.2.2 Determined weight of each criterion

In order to determine weight of each criterion, the following steps have been illustrated.

a) Indicated pairwise comparison matrices

To obtain the weights, we begin by forming a matrix A, known as at pairwise comparison matrix. The entry in row "i" and column "j" of A, labeled a_{ij}, indicates how much more (or less) important objective "i" is than objective "j". In order to build a consistency matrix, pairwise comparison matrix is required $a_{ji} = 1/a_{ij}$ is to be set for each *i* and *j*, as illustrated in following pairwise comparison matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} \; (1/a_{12}) & a_{22} & a_{23} & a_{24} \\ a_{31} \; (1/a_{13}) & a_{32} \; (1/a_{23}) & a_{33} & a_{34} \\ a_{41} \; (1/a_{14}) & a_{42} \; (1/a_{24}) & a_{43} \; (1/a_{34}) & a_{44} \end{bmatrix}$$

The value of a_{ij} has been set as "Importance" which is measured on an integer-value 1-9 scale with each number having the interpretation shown in table 2, as follow;

Table 2: Interpretation of values in pairwise comparison

Value of a_{ij}	**Interpretation**
1	Objective "i" and "j" are equally important
3	Objective "i" is slightly more important than "j"
5	Objective "i" is strongly more important than "j"
7	Objective "i" is very strongly more important than "j"
9	Objective "i" is absolutely more important than "j"

b) Normalized Pairwise comparison matrices A to get A*

For each of the columns of A, divide each entry in the column by the sum of the entries in the column, this yields a new matrix (call it A_{norm}, for "normalized) in which the sum of the entries in each column is 1

$$a_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

c) Estimated the weight for criterion "i"

Estimate the weight for objective "i" (w_i), as the average of the entries in row "i" of A_{norm*}.

$$W_i = \frac{\sum_{j=1}^{n} a_{ijl}}{n}$$

3.2.3 Checking for consistency

Any pairwise comparison matrix can suffer from inconsistencies. Therefore, checking of inconsistencies is obviously critical process.

a) Calculation AW

As illustrated on the A matrix, it is associated vector of weights *w*. However, the same procedure can be used on any of the A_i matrices and their associated "weights" vector S_i.

b) Calculation λ_{max}

Find the ration of each element of AW to the corresponding weight in w and average these ratios.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

c) Calculation the constancy index (CI), when "*n*" is the number of objectives

$$CI = \frac{\lambda_{max} - n}{n-1}$$

d) Calculation the consistency ratio (CR)

$$CR = \frac{CI}{RI}$$

Random index (RI) is indicated by the following table for the appropriate value of *n*.

Table 3: Random indices for consistency check for AHP

No	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.51

For a perfectly consistent decision maker, CI is equal to 0 (CI=0). If the ratio of CI to RI is sufficiently small, then the decision maker's comparisons are probably consistent enough to be useful.

According to Saaty's suggestion, if CR = CI/RI < .10, then the degree of consistency is satisfactory, whereas if CI/RI > .10, serious inconsistencies exist and AHP may not yield meaningful results.

3.2.4 Determined the scores of each alternative on each criterion

The determination of the score of each alternative will be determined by scored each decision alternation on each object in order to define how well each alternative score on each objective. The pairwise comparison matrix and the whole process has been duplicated in this case.

3.2.5 Calculation an overall score

This step is to combine the score in the S_i vectors with the weights in the w vector by multiply matrix S of the score vectors by matrix w then a vector of overall scores for each alternative is obtained.

Chapter 4   Data Collection

Data collected in this research consists of both quantitative and qualitative data. All of these data is collected by conducting field observation and collecting data from SSS-Thanee Food Co., Ltd to study inventory and distribution pattern of the company under normal circumstances as well as an impact of an unexpected event that disrupted the company supply chain from the flood that occurred during third quarter and the early fourth quarter in 2011 in Thailand.

4.1 Company Overview

SSS-Thanee Food Co., Ltd is a Thai SMEs manufacturer that produce pet snack as original equipment manufacturer (OEM) mainly exporting to Japan. The company invests in mini factory in ready- made factory town, named MPC Home Factory, located in Phra Pradaeng district, Samutprakarn Province. The location is nearby outer ring that can directly connect to South, East and West of outer ring in order to go to Rama 2, Samudsakhon, Nonthaburi, Bangna-Trad, and Suvarnabhumi airport. All these routes are easily accessible to various business center areas as well as Laem Chabang Port, Chonburi.

As mentioned that the company invests in mini factory, the area of first story is 200 sq.m, combined with production line included mixing area as well as packing room. Second story area is 150 sq.m that used as finished goods inventory, packaging and miscellaneous inventory as well as inventory office zone. On the second floor, the actual finished goods inventory area is approximately 25sq.m.

With small useable area, inventory space is often been a critical issue of high congestion. The company does not have enough space of keep the excessed inventory.

4.2 Existing Operation Flow and Inventory Management

"JIT" or "Pull" system is an initial concept of the company, once invests in this mini factory, in order to minimize all type of inventory as much as possible; raw material, in progress, finished goods and maintenance, repair and tooling inventories.

The company expected that inventory both flow in and flow out are on schedule. Both orders are really constant, certain demand for long term. Inventory area has been counted as small portion area only for carrying short team transit. Eventually, company invests in this mini factory and obviously applies "Lean system" to manage inventory flow in order to minimize inventory carrying cost.

4.2.1 Finished goods cycle stock

The company has two long term contracts, for one year, with irrelevant customers from Japan through different agent. However, these two orders have been signed on monthly shipment but in different period of time; every 25th for order A and every 10th of order B, in other word the company has to deliver the order every two week.

First contract, product A, has been signed in monthly delivering 3.5 tons of the product to each customer. Finished goods have been separately packed in box with dimension of 45cm x 40cm x 42cm before stuffing in a 20 TEU container. Total stuffed boxes in 20TEU container are approximately 350 boxes per shipment; therefore each box is contained 10 kilogram of pet snack.

The second contract, product B, has been signed also in monthly delivering of 4 tons of products. This order are also been packed separately in 28cm x 38cm x 30cm box size before stuffing in the 20TEU container. Therefore, there are also approximately 800 boxed per lot size with 5 kilogram per box.

With approximately 10 kilograms per boxes of product A, the stacked high is supposed to be one box over four, or not over five boxes per column, otherwise the product at the bottom row is possible be damaged due to the heavy pressure.

Table 4: The area require for each lot size with 5 boxes stacking high

Order	Box Size (cm)	Average No. of Box	Avg. weight per box (kg.)	Area Require (sq.m.)
1	45x40x42	350	10	15
2	28x38x30	800-840	5	17

4.2.2 Raw Material cycle stock

According to produce pet snack for both customers, major ingredients are similar, with different minor additive, ingredients' proportion of each product are also different. With some similar and some different ingredients, six suppliers have been involved in supplying raw material to the company.

In order to produce 1 ton of each product, different amount of each item from each supplier is to be concerned. The amounts of order of each lot size require different inventory space. However, each item will not be stacked over 5 rows due to the convenience of the moving and operating.

Table 5: The require area of raw material of each product per lot size

Item	Package Size (cm)	Product A	Area (sq.m.)	Product B	Area (sq.m.)
S1	51x92	40%	5	30%	4
S2	51x92	15%	2	25%	4
S3	51x92	15%	2	10%	2
S4	35x55	10%	2	8%	2
	20x38	-	0	7%	1
S5	40x60	8%	3	11%	5
	20x38	4%	1	-	0
S6	40x60	8%	2	4%	1
	20x38	-	0	5%	1
	Total Area		17		20

According to the mentioned proportion of producing each product from above table (Table 5), the amount of the proportion in each item that is used in producing one lot size of both products is different. Moreover, each item has different size of packages, as called per unit in this report. The amount of unit that is used in each item in order to produce 3.5 tons of "Products A" and 4 tons of "Product B" is also varies. The number of unit of each item that is used to produce each lot size is shown in the table 6, as shown below.

Table 6: The unit amount of each item used in producing each lot size

Supplier	Item	Product A Unit	Product B Unit
1	1	49	40
2	2	18	36
3	3	18	16
4	4	35	32
	5	0	56
5	6	56	88
	7	28	0
6	8	28	16
	9	0	40

Item from supplier 1 and supplier 3 have to keep in specified temperature control before starting the production. Therefore, on the first floor also has built temperature control storage room in order to keep these two items. The rest items are able to keep in normal room temperature.

4.2.3 Defected product, equipment and packaging inventory

The company sincerely accepts that each lot size has approximately 5%-10% defected or under qualified product. This defected inventory has been kept on the second floor as finished goods but different corner. However, reverse logistic is not been concerned in this research, which sometimes customer has also complained about defected around one to five boxes which is not worth to return to the company. However, the customer requests to send replacement in additional to the next lot size, remarked as backlog order. Otherwise, the company has to deliver through less than container loaded (LCL), joining with other customer of the agent because the TEU container is not enough space to stuff.

Besides defected product, all equipment and packaging are also stored on the second floor, for example packing boxes, zip-locked plastic bag, label and miscellaneous equipment. These inventories are flown in and out quite large amount per lot size, which is delivered for both order at the same time with the same suppliers. These inventory areas are taken approximately 25 sq.m. on the second floor.

4.2.4 Company work flow with "Pull System" (JIT) and Work in Progress Inventory system

Comparing with factory usable area space and minimum required space of both finished goods and raw material as well as defected inventory, the company is inevitable to apply pull system or JIT system as well as keep zero inventory in both finished goods and raw material, otherwise, the traffic problem will be occurred due to high congestion in the factory.

Therefore, when all raw materials are arrived at the factory, they are directly put in the production line; in mixing room and immediately start all the processes. However, all raw materials are not arrived at the same time even quite the same period of time.

The company has really tide timeline in manufacture and packing each lot size. The schedule must be accurate as much as possible. From the tided schedule below (Figure 3), the company really required on time and accurate timeline process, there is no any room for miss or mistake.

Figure 3: Three months production schedule

Source: SSS-Thanee Food Co., Ltd.

In fact, most of the time production of “Order 2” is delay, overlap with “Order 1” new production period, as well as “Order 1”. Cause of delay is some from supplier that delay delivery raw material, some from too much defected on that lot size until has to be reproduced.

4.3 Company Inventory Flow as centralization

Currently, all inventory flow and distribution are centralized through the factory. Suppliers directly deliver raw materials to the factory. The arrival time from each supplier is quite close. When all raw materials are readily prepared, they are all moved and started the production process at the mixing room.

Later, when the production is completed, finished goods are packed and storaged at the factory. Until due date, the whole lot size is directly delivered from the factory to the agent permis. As shown in figure 4

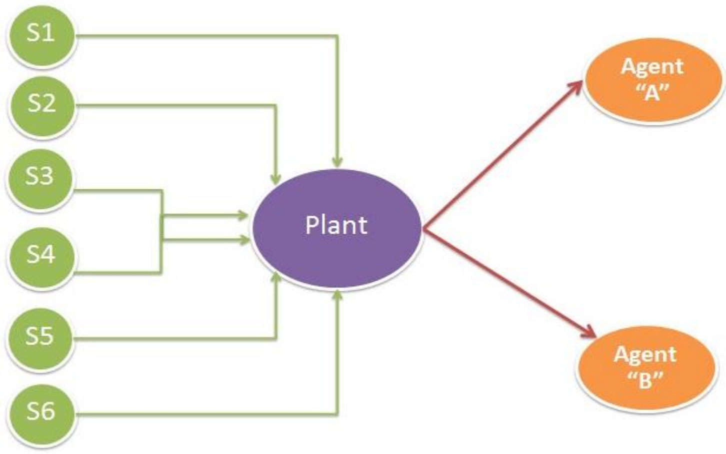


Figure 4: Existing inventory flow as centralization
Source : SSS-Thanee Food Co.,Ltd.
Draw : Author

From the figure above, the company has to face with tided inventory flow schedule because the factory is centralized all inventory at the same place and time in combined with limited inventory space. Therefore, any missed schedule is occurred, overwhelm inventories would be immediately caused high congestion traffic problem.

4.4 The Impact from Flood 2011

According to the flood in Thailand 2011, approximately 10,000 factories have been impacted in both direct and indirect way. SSS-Thanee Food Co., Ltd is also the one that impact and made lost from this event. Even the factory is not flood, the lost is occurred; due to lack of inventory and distribution problem.

a) Termination of production line

Zone and surrounding area of the factory location is not directly impact to the flood. All activities around that area are normally run as usually. However, the factory is also affected because S1, S4, S5 and S8 are not able to supply raw materials to the company. Therefore, the production line is not able to start in both orders. The company is not able to completely find the substitute of all items. Therefore, production line is inevitable terminated for two months.

Consequently, S3 lot size, as mentioned above that require temperature control storing, has been expired. The whole lot size of S3 has to be reordered, when the production line is able to be restarted. This creates waste cost to the company.

b) Stabilized finished inventory

Distribution is another problem during the flood crisis. Not only raw materials are not able to flow in, but the whole lot size of "Order 2" is stabilized in the inventory also. The agent logistics service is not available to access to pick the order and deliver to the agent premise also.

According to the unexpected flood, the company obviously lost 5 orders within 2 months. Even both customers realize situation and problem; they do not charge any penalty to the company. However, the company realizes the opportunity cost due to lost sales. Another consequence is renewal contract period has to be prolonged for another two months because the company has to fulfill those 5 missing orders during the flood crisis.

Chapter 5 Research on Company Criterion

This chapter is focused on the research of company criterion in order to deal with the disruption in supply chains. The research will be analyzed step by step that has been explained in chapter 3 by using the based data that is presented in the chapter 4. The research will be focused on both increasing inventory stock, safety stock and decentralized are concerned by the company as preventive plan as well as mitigate loss of disruption.

5.1 Increasing of inventory stock level

Due to increasing level of safety stock, the company has divided into two parts;

(1) Finish goods that is already packed and

(2) Raw materials that are delivered by different suppliers.

5.1.1 Finished goods

In the study of safety stock, demand and lead time are critical factors that have been counted in order to calculate the level of safety stock, as well as service factors level. In order to calculate proper safety stock of the finished goods, the company applies formula as follow:

$$SS = Z * \sigma D * \sqrt{LT}$$

When:

SS	=	Safety Stock
Z	=	Service factor
σD	=	Standard Deviation of Demand
LT	=	Lead Time

5.1.1.1 Demand of "Product A" and "Product B"

Even both contracts have been signed in specified amount of the product; 3.5 tons and 4 tons respectively; the actual demand in each month is quite flexible. However, the delivery unit is counted as box size, approximately 350 boxed and 800 boxes per shipment in contract A and contract B respectively. Therefore, in this research will be specified demand of each product by delivered box.

According to the delivery record of two consecutive years 2010 and 2011, it is shown that demand in each month is vary. However, at the end of third quarter and early of fourth quarter of 2011, disruption has been occurred around Bangkok and surrounding area which caused indirect impact to the company during August – October 2011. The company is not able to fulfill the contract during those months. The monthly delivery of both products has been shown in the following tables:

Table 7: Monthly delivery in two consecutive yearo of Product A

Month	**Amount of Delivery Product A (box)**	
	2010	2011
Jan	350	350
Feb	350	340
Mar	320	350
Apr	360	350
May	330	320
Jun	350	330
Jul	370	320
Aug	360	350
Sep	360	-350
Oct	350	-350
Nov	350	**350**
Dec	350	**350**

Table 8: Monthly delivery in two consecutive year of Product B

Month	Amount of Delivery Product B	
	2010	2011
Jan	800	800
Feb	800	820
Mar	800	820
Apr	820	840
May	780	800
Jun	820	820
Jul	750	800
Aug	800	-800
Sep	820	-800
Oct	810	-800
Nov	800	**800**
Dec	800	**800**

From the above two tables (Table 7 and Table 8), the company is totally missed to delivery five orders in those three disrupted months, two orders from Product A and three orders from Product B. However, those five orders have been actually accumulated in the following period after the disruption has terminated. The presence amount of delivery in November and December of 2011 is an initial expected order that is required to be delivered.

Due to the limited capacities of the company, the accumulated amount of order has been completely fulfilled during the early 2012. However, this research will be counted the delivered demand only at the end of 2011. Therefore, the actual demand that has to be delivered in year 2011 will be shown in the following table.

Table 9: Actual delivered unit of each product in 2011

Month	2011	
	A	B
Jan	350	800
Feb	340	820
Mar	350	820
Apr	350	840
May	320	800
Jun	330	820
Jul	320	800
Aug	300	-
Sep	-	-
Oct	-	-
Nov	500	1000
Dec	550	1000

5.1.1.2 Lead time

Lead time in delivering each order has been specified in both contracts that each order has to be delivered every 30 days. Therefore, we assume that the lead time of finished goods is 30 days for each order.

5.1.1.3 Service factors

The higher service level, the higher safety stock level is required. The company needs to reach high service level due to satisfy customer. Moreover, the company realizes that this OEM market is high competitive market. Plenty of competitors are available in the market. The customer is able to abandon the company and hire competitor every moment.

However, the company has considered three service levels in order to calculate safety stock level in this research: 95%, 97% and 99%. The company has test various service level because the company has to justify with the capacity of the production line in order to produce safety stock in each period.

Table 10: Service factor in research

	Scenario 1	Scenario 2	Scenario 3
Service Level	95%	97%	99%
Service Factor	1.64	1.88	2.33

5.1.1.4 Safety Stock Level in Each Scenario

This calculation will be compared between normal circumstance of 2010 and disrupted circumstance of 2011.

In order to find the standard deviation of demand (σD), this research will used function STDEVP in excel sheet, the result is in the following tables;

Table 11: Standard deviation of demand in Product A

Month	Amount of Delivery Product A	
	2010	**2011**
σD	12.91	79.30

Table 12: Standard deviation of demand in Product B

Month	Amount of Delivery Product B	
	2010	**2011**
σD	18.71	78.19

After calculating standard deviation of the demand in both products in two consecutive years, safety stock level has been calculated. This calculation need to compare the required safety stock level in both normal circumstance and disrupted situation.

Table 13: The level of safety stock required in service level

Safety stock Level	Product A		Product B	
	2010	2011	2010	2011
Scenario 1	116	713	169	703
Scenario 2	133	817	193	806
Scenario 3	165	1013	239	998

According to the above table (Table 13), safety stock level in normal circumstance and disrupted circumstance is extremely high gap in each scenario, approximately 2-3 times larger in disrupted circumstance. It is obviously that holding too extreme safety stock create huge exaggerated cost to the company because disruption is not an ordinary situation as well as the capacity of the production line is also limited to 6 tons per order. Therefore, the company decided to select the data base of 2010 with 97% service level to set up safety stock level; 133 boxes for product A, and 193 boxes for product B.

(The amount of delivery units in November and December is realized that it is not the exact required demand of the total annual demand. The rest of amount has been fulfilled in the first quarter of 2012, which is not count in this research.)

5.1.2 Raw material

The study shows three factors that affect to level of safety stock, including demand, lead time and service factor. However, calculating safety stock of raw material is more complex than finish goods because the company has to deal with 9 major items from six suppliers.

Different suppliers are lead to vary in lead time of each item. Moreover, demand of each item is varied due to the proportion of the ingredient in each product as well as demand of the customer.

With these varies of both demand and lead time, the formula of calculating safety stock level is applied as follow equation:

$$SS \quad = \quad Z * \sqrt{\overline{LT} * \sigma_d^2 + \overline{D} * \sigma_{LT}^2}$$

When:

SS	=	Safety Stock
Z	=	Service factor
$\overline{LT}$	=	Average lead time
σ_d	=	Standard deviation of demand
$\overline{D}$	=	Average demand
σ_{LT}	=	Standard deviation of lead time

5.1.2.1 Demand of Raw Material

Demands of raw materials are interrelated with the demand of finished goods. Nine items of raw materials are counted in order to produce both products in different proportion as mention in chapter 4. However, the actual demand of finished goods of both products in 2010 and 2011 are affected to the amount of unit required of each item. The number of unit that used in order to product “Product A” and “Product B” in year 2010 and 2011 are shown as following tables:

Table 14: Number of unite used in each item to Product A 2010

Month 2010	S1	S2	S3	S4		S5		S6	
	I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I 9**
Jan	49	18	18	35		56	28	28	
Feb	49	18	18	35		56	28	28	
Mar	45	16	16	32		52	26	26	
Apr	51	18	18	36		58	29	29	
May	47	17	17	33	-	53	27	27	-
Jun	49	18	18	35		56	28	28	
Jul	52	19	19	37		60	30	30	
Aug	51	18	18	36		58	29	29	
Sep	51	18	18	36		58	29	29	
Oct	49	18	18	35		56	28	28	
Nov	49	18	18	35		56	28	28	
Dec	49	18	18	35		56	28	28	
STDEV	**1.83**	**0.69**	**0.69**	**1.29**		**2.09**	**0.99**	**0.99**	
AVERAGE	**49.25**	**17.83**	**17.83**	**35.00**		**56.25**	**28.17**	**28.17**	

Table 15: Number of unit used in each item to Product A 2011

Month 2011	S1	S2	S3	S4		S5		S6	
	I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I 9**
Jan	49	18	18	35		56	28	28	
Feb	48	17	17	34		55	28	28	
Mar	49	18	18	35		56	28	28	
Apr	49	18	18	35		56	28	28	
May	45	16	16	32		52	26	26	
Jun	47	17	17	33		53	27	27	
Jul	45	16	16	32		52	26	26	
Aug	42	15	15	30		48	24	24	
Sep	0	0	0	0		0	0	0	
Oct	0	0	0	0		0	0	0	
Nov	70	25	25	50		80	40	40	
Dec	77	28	28	55		88	44	44	
STDEV	**21.87**	**7.91**	**7.91**	**15.61**		**24.99**	**12.51**	**12.51**	
AVERAGE	**43.42**	**15.67**	**15.67**	**30.92**		**49.67**	**24.92**	**24.92**	

The above two tables (Table 14 and Table 15) are shown the demand of each item that use to produce “Product A” in 2010 and 2011.

Moreover, the standard deviation as well as average demand of each raw material item of “Product A” in 2010 and 2011 has also been shown in the tables.

Table 16: Number of unite used in each item to Product B 2010

Month 2010	S1	S2	S3	S4		S5		S6	
	I1	I2	I3	I 4	I5	I6	I7	I 8	I9
Jan	40	36	16	20	56	88		16	40
Feb	40	36	16	20	56	88		16	40
Mar	40	36	16	20	56	88		16	40
Apr	41	37	17	21	58	91		17	41
May	39	36	16	20	55	86		16	39
Jun	41	37	17	21	58	91		17	41
Jul	38	34	15	19	53	83		15	38
Aug	40	36	16	20	56	88		16	40
Sep	41	37	17	21	58	91		17	41
Oct	41	37	17	21	57	90		17	41
Nov	40	36	16	20	56	88		16	40
Dec	40	36	16	20	56	88		16	40
STDEV	**0.86**	**0.80**	**0.60**	**0.60**	**1.36**	**2.21**		**0.60**	**0.86**
AVERAGE	**40.08**	**36.17**	**16.25**	**20.25**	**56.25**	**88.33**		**16.25**	**40.08**

Table 17: Number of unit used in each item to Product B 2011

Month 2011	S1	S2	S3	S4		S5		S6	
	I1	I2	I3	I4	I5	I6	I7	I8	I9
Jan	40	36	16	20	56	88		16	40
Feb	41	37	17	21	58	91		17	41
Mar	41	37	17	21	58	91		17	41
Apr	42	38	17	21	59	93		17	42
May	40	36	16	20	56	88		16	40
Jun	41	37	17	21	58	91		17	41
Jul	40	36	16	20	56	88		16	40
Aug	0	0	0	0	0	0		0	0
Sep	0	0	0	0	0	0		0	0
Oct	0	0	0	0	0	0		0	0
Nov	50	45	20	25	70	110		20	50
Dec	50	45	20	25	70	110		20	50
STDEV	**18.83**	**16.97**	**7.62**	**9.48**	**26.44**	**41.55**		**7.62**	**18.83**
AVERAGE	**32.08**	**28.92**	**13.00**	**16.17**	**45.08**	**70.83**		**13**	**32.08**

The above two tables (Table 16 and Table 17) are shown the demand of each item that use to produce "Product B" in 2010 and 2011, as well as standard deviation and average demand of each raw material item.

If compare the standard deviation of demand of both products in years 2010, the deviation is quite low, while 2011 the deviation is really high due to the disruption at the second half of the year.

5.1.2.2 Lead Time

Lead time of raw materials are also varies due to dealing with six suppliers. Each supplier has different delivering lead time and varies in each delivering. As mentioned on chapter 3 that the company has really small area. Therefore, the supplier has to deliver item twice per month in different amount of unit depended on produced product order. Lead time of each item that is delivered is varied in different period of time as show in the following table.

Table 18: Lead time of each item to produce Product A 2010

Month 2010	**S1**	**S2**	**S3**	**S4**		**S5**		**S6**	
	I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I9**
Jan	6	5	5	5		7	7	5	
Feb	5	5	4	3		8	8	6	
Mar	4	4	5	4		6	6	5	
Apr	7	3	5	5		9	9	7	
May	5	6	7	2		7	7	6	
Jun	7	2	3	8		6	6	4	
Jul	6	7	5	6		4	4	8	
Aug	8	3	5	5		7	7	6	
Sep	10	5	7	4		9	9	5	
Oct	9	4	3	4		7	7	3	
Nov	6	6	5	7		6	6	8	
Dec	7	7	4	8		4	4	6	
STDEV	**1.65**	**1.53**	**1.21**	**1.80**		**1.55**	**1.55**	**1.42**	
AVERAGE	**6.67**	**4.75**	**4.83**	**5.08**		**6.67**	**6.67**	**5.75**	

Table 19: Lead time of each item to produce Produce A 2011

Month 2011	S1	S2	S3	S4		S5		S6	
	I1	I2	I3	I4	I5	I6	I7	I8	I 9
Jan	7	5	5	5		8	8	6	
Feb	8	6	3	7		7	7	5	
Mar	7	6	4	5		6	6	6	
Apr	7	4	3	3		8	8	5	
May	5	5	6	8		6	6	8	
Jun	6	5	4	4		6	6	6	
Jul	7	4	4	3		8	8	9	
Aug	12	12	9	2		12	12	10	
Sep									
Oct									
Nov	60	45	40	60		60	60	60	
Dec	12	15	15	15		15	15	14	
STDEV	**15.79**	**11.95**	**10.81**	**16.65**		**15.71**	**15.71**	**15.92**	
AVERAGE	**13.1**	**10.7**	**9.3**	**11.2**		**13.6**	**13.6**	**12.9**	

The above two tables (Table 18 and Table 19) indicate lead time of each item that is delivered by supplier in order to supply for "Product A" in 2010 and 2011 as well as standard deviation and average LT.

Table 20: : Lead time of each item to produce Product B 2010

Month 2010	S1	S2	S3	S4		S5		S6	
	I1	I2	I3	I4	I5	I6	I7	I8	I9
Jan	7	4	4	4	4	9		6	6
Feb	6	7	5	5	5	8		4	4
Mar	6	5	3	4	4	9		8	8
Apr	6	4	4	4	4	7		5	5
May	5	7	7	6	6	5		6	6
Jun	8	5	4	7	7	7		4	4
Jul	6	7	4	4	4	9		6	6
Aug	9	4	2	3	3	7		5	5
Sep	10	5	7	4	4	6		8	8
Oct	9	7	5	6	6	9		6	6
Nov	6	6	4	5	5	8		5	5
Dec	7	5	5	6	6	7		7	7
STDEV	**1.50**	**1.19**	**1.38**	**1.14**	**1.14**	**1.26**		**1.28**	**1.28**
AVERAGE	**7.08**	**5.50**	**4.50**	**4.83**	**4.83**	**7.58**		**5.83**	**5.83**

Table 21: Lead time of each item to produce Product B 2011

Month 2011	S1	S2	S3	S4		S5		S6	
	I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I9**
Jan	8	5	5	6	6	9		8	8
Feb	8	6	6	5	5	7		6	6
Mar	7	5	7	7	7	4		5	5
Apr	7	6	4	4	4	8		8	8
May	6	4	9	2	2	6		6	6
Jun	8	3	3	5	5	8		9	9
Jul	9	15	14	4	4	12		11	11
Aug									
Sep									
Oct									
Nov	90	60	55	90	90	90		90	90
Dec	14	12	14	23	23	14		11	11
STDEV	**25.74**	**17.06**	**15.32**	**26.73**	**26.73**	**25.77**		**25.85**	**25.85**
AVERAGE	**17.44**	**12.89**	**13.00**	**16.22**	**16.22**	**17.56**		**17.11**	**17.11**

The above two tables, (Table 20 and Table 21), indicate lead time of each item that is delivered by supplier in order to supply for "Product B" in 2010 and 2011 as well as standard deviation and average LT.

As shown in table 20 and table 21, the average lead time of each item is around 4-7 days in normal circumstance. While in 2011, the average lead time is increase to approximately 10-17 days. However, the disruption is occurred in a period of time that causes high average of lead time.

5.1.2.3 Service Factor

In order to specify service level of raw materials, the company decides to examine similar level of finished goods, 95%, 97% and 99%. The similar factors will be lead to closed interrelate between finished goods and raw material. Moreover, the company also needs to estimate area and capacity that required holding all these safety stock.

5.1.2.4 Raw Material Safety Stock Level

The company also calculates level of safety stock in three scenarios: 95%, 97% and 99% of service level has been clarified same as finished goods as well as in both circumstances; normal distribution and disruption distribution. The level of safety stock of each item in each scenario is shown in the following tables;

Table 22: Safety stock required unit of each item varied by service level of 2010

2010 Normal Distribution		Scenario 1		Scenario 2		Scenario 3	
		Product A	Product B	Product A	Product B	Product A	Product B
S1	**I1**	21	16	24	19	30	23
S2	**I2**	11	13	13	14	16	18
S3	**I3**	9	10	11	11	13	14
S4	**I4**	19	9	21	10	26	13
	I5		15		18		22
S5	**I6**	21	22	25	25	30	31
	I7	15		17		21	
S6	**I8**	13	9	15	11	19	13
	I9		14		16		20

Table 23: Safety stock required unit of each item varied by service level of 2011

2011 Disruption Distribution		Scenario 1		Scenario 2		Scenario 3	
		Product A	Product B	Product A	Product B	Product A	Product B
S1	**I1**	215	272	246	312	305	387
S2	**I2**	89	181	102	208	126	257
S3	**I3**	81	102	93	116	115	144
S4	**I4**	175	188	200	215	248	266
	I5		343		393		487
S5	**I6**	237	457	271	523	336	648
	I7	150		172		213	
S6	**I8**	150	162	172	185	213	230
	I9		272		312		387

From above two tables (Table 22 and Table 23), the company decides to focuses on the level of safety stock of normal distribution rather than disruption distribution as same as finished goods. However, the company has justified level of safety stock each item separately because each item from each supplier has different criterion.

After considering the safety stock level of each item from different scenario, the company makes a decision to mainly apply scenario 2 or 97% of safety stock level to Item 1, 4 and 6 for both “Product A” and “Product B” in order to be interrelated with the finished goods. However, the company applies scenario 1, 95% of service level for Item 2, and 3 as well as scenario 3, 99% service level of Item 6.

The average lead time of item 2, 3, 4 and 6 is around 4-5 days of both products. However, the company find out that during the crisis only supplier 2 and 3 did not affected with the flood. Moreover, item 3 is required to keep in controlled temperature then the company does not to holding too much unit. Therefore, the company decides to apply scenario 1 to these two items. Even item 1 also required controlled temperature as item 3, scenario 2 is applied to item 1 because this supplier has a risk from disruption and average lead time is around 7 days. However, item 6, which has 7 days average lead time as item 1, is applied scenario 3 because item 6 does not need to be concerned about temperature control as item 1. The most important is that this item 6 has small number of supplier.

5.2 Company decentralization with AHP Model

According to the flood, the company is more interested in the concept of decentralization. Initial reason is to diversify risk that is possible to be randomly occurred due to the disruption as preventive plan. Moreover, the company, as mentioned above, is really small. When safety stock has been concerned in order to deal with the disruption in supply chains, the company needs more area for those stocks of both finished goods and raw materials.

New warehouse is eventually decided to store finished goods before distributing to the agents. Even this research is focused only on export product of the company, domestics distribution is taken into consideration as well. This new warehouse is mainly used for store finished goods both export and domestic sales. Therefore, factors of both export and domestics sales have to be concerned in order to find the best alternative of the new warehouse location.

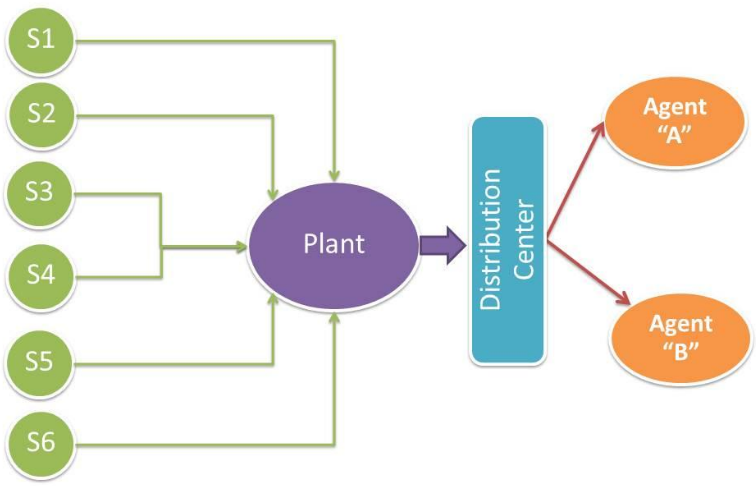


Figure 5: New proposed flow of inventory as decentralization

In order to select the best alternatives of the warehouse, AHP model has been applied in this solution to support multi criteria decision making.

5.2.1 Indicated factors of AHP model

With the topmost goal is to select the new warehouse, the problem has been decomposed into components, including criterion and sub criterion at the intermediate level and alternatives or options at the lowest level.

The alternative warehouses that the company is interested in including three warehouses in different three locations. There are located in Phra Pra Daeng, Lard

Krabang and Bang Phra Kong district. These three locations are interested in various industrial aspects; completed industrial facilities and infrastructure, easy to access with various connections, the area is flexible for future expansion as well as the risk agile, natural disruption.

The criterion of this problem has been classed into four major criterion; location and transportation, cost, capacity and flexibility as well as infrastructure. All these components have been structured into the hierarchy in the following figures.

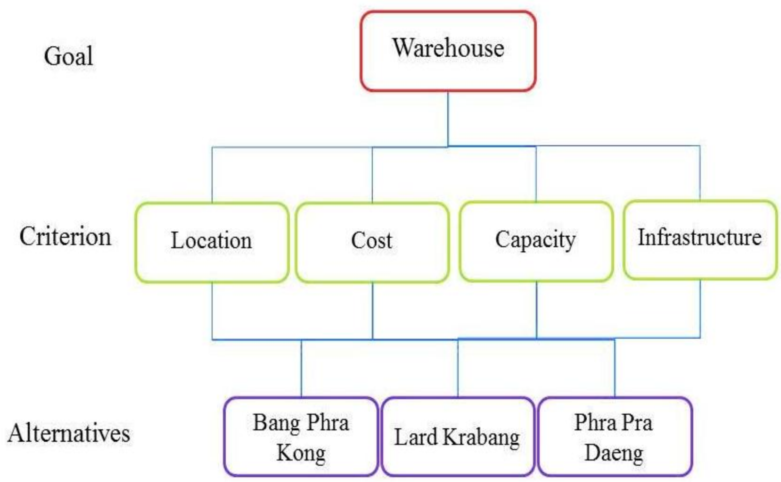


Figure 6: AHP hierarchy for the best selected warehouse

Criterion of the problem

Four criterions have been involved in this problem, including location, cost, capacity & flexibility and infrastructures. Each criterion will be defined and specified as follow;

a) Location criteria

Besides site of the warehouse, location is also indicated about the accessibility as well as connection to the market. The company also considers about the ease to access from the factory to the site as well as from the site to the agent premise and market. The path that is suit for various kind of road transported vehicle is also considered because various type of vehicles, since small picked up car until huge container truck. If the path is not really support all those kind of vehicles, especially truck, the flow of the traffic is highly possible be struck, which really wasted time of transportation. Moreover, various alternative connections that link to the site are concerned as risk agile. If there is an unpredictable incident that stuck the flow of the traffic, the company still has alternative to avoid that route in order to continuity the business.

b) Cost criteria

Cost is obviously a critical factor that the company has to be concerned. The company is SMEs that does not have a huge number in the financial statement for huge investment. There are three major cost that are concerned, leasing cost, transportation cost and administrative cost. The major cost is leasing cost. The company decide to lease instead of building own warehouse in order to reduce the cost of investment as well as reduce time of applying the decentralized concept. However, leasing cost has to be compared between each alternative.

Secondly, transportation cost is considered about transporting finished goods from the factory to the warehouse and the warehouse to the agent premise. Transporting cost is mainly includes driver salary, fuel cost, that transport the order from the factory to the warehouse as well as hiring cost of third party logistics that transport the order from the warehouse to the agent premise.

Thirdly, the administrative cost is only counted the administrative cost and transaction cost that occurred in order to transfer the finished goods of both export lot size as well as domestic sales from the factory to the warehouse and the warehouse to the agent premise. Any other administrative cost as well as transaction cost that is not involved in this transferring finished goods will not be count at this point in time.

c) Capacity criteria

This criterion is not only focused on the site of the warehouse but considered about surrounding zone also. Firstly, the capacity of the warehouse is mentioned in the capacity that required in normal distribution as well as temporary additional capacity, besides normal leasing space. The temporary additional capacity is also involved in the flexibility of the warehouse operation in normal situation and unexpected incident as well as natural disruption.

The flexibility is also mention about the flexibility of the usage of the surrounding area. The permission of develop and usage of that zone, whether it is able to develop for industrial zone as the potential of future expansion. The company is also looking for its own expansion as extend the production line around that new warehouse as long term plan, which will not mention in this research.

d) Infrastructure criteria

Infrastructure of the leased warehouse is another factor that has been considered. Infrastructure is not only concerned about necessary utilities, as water supply, electric supply, but other involved facilities are also concerned, such as the equipment that is for warehouse operation, information technology systems, and so on. The infrastructure is also included the surrounding facilities surrounding the warehouse that can make ease in the logistics system such as fuel supply, logistics services providers and so on.

All these four criteria are the main factors that the company is taken into account. However, all three alternatives are match to all these criterions but in different level at different factors. Initially, pairwise comparison matric

5.2.2 Determined weight of each criterion

Pairwise comparison matrix has been initially indicated in order to determine weight of each criterion. However, the judgment of this pairwise comparison matrix has been defined according to the actual study and discussion together with the executive management of the company. Pairwise comparison has been shown as following table, table 24.

Table 24: Pairwise comparison matric of criteria

	Location	**Cost**	**Capacity**	**Infrastructures**
Location	1	3	5	3
Cost	1/3	1	5	3
Capacity	1/5	1/5	1	1/3
Infrastructures	1/3	1/3	3	1

a) Normalized Pairwise comparison matrices A to get A*

The above pairwise comparison matrix has been normalized to obtain A* or A_{norm}, with the sum of the entries in each column is 1. The calculation has been shown in the following table.

Table 25: Normalized pairwise comparison matrices, as A*

$a_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$	**Location**	**Cost**	**Capacity**	**Infrastructures**
Location	0.5357	0.6618	0.3571	0.4091
Cost	0.1786	0.2206	0.3571	0.4091
Capacity	0.1071	0.0441	0.0714	0.0455
Infrastructures	0.1786	0.0735	0.2143	0.1364

b) Estimated weight for criterion "i"

The weight of each criterion has been estimated the weight for objective "i" (w_i), as the average of the entries in row "i" of A_{norm*}. The weight score has been computed as shown in the table 26 below.

Table 26: Weight of criteria

Wi	$W_i = \frac{\sum_{j=1}^{n} a_{ij}l}{n}$	Location	0.4909
		Cost	0.2913
		Capacity	0.0670
		Infrastructure	0.1507

5.2.3 Checking for consistency

The consistency has been checked to avoid the possibility of suffering from uncertainty that would be occurred from pairwise comparison matrices, with suggested satisfied consistency ratio less than 0.10, CR <0.10.

a) Calculation Aw

The calculation of AW is to combine the pairwise comparison matrix, A, with weight of each criterion, W_i. The score of Aw has been computed as shown in the following table, table 27.

Table 27: Score of AW

AW =	Location	2.1522
	Cost	1.2422
	Capacity	0.2737
	Infrastructure	0.6126

b) Calculation λ_{max}

λ_{max} has been calculated to find the ratio of each element of Aw to the corresponding weight in *w* and average these ratios. The ratio result of λ_{max} has been show in the following table, table 28.

Table 28: Result of λmax

$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$	$\frac{2.1522}{4 * 0.4904} + \frac{1.2422}{4 * 0.2913} + \frac{0.2737}{4 * 0.0670} + \frac{0.6126}{4 * 0.1507}$
	4.1990

c) Calculation of constancy index (CI), when "*n*" is the number of objectives

The constancy index result has been shown in the following table, table 29.

Table 29: Result of consistancy index

$CI = \frac{\lambda_{max} - n}{n - 1}$	$\frac{4.1900 - 4}{4 - 1}$
	0.0663

d) Calculation of the consistency ratio (CR)

The consistency ration has been calculated, divided consistency ration by random index of "n", 4 = 0.9. The result has been illustrated in the following table, table 30.

Table 30: Result of consistency ratio

$CR = \frac{CI}{RI}$	$\frac{0.0663}{0.9}$
	0.0737

According to the calculating consistency ration, the pairwise comparison of criterion is obviously consistency, CR = 0.0737 which is less than 0.1.

5.2.4 Determined the Scores of each Alternative on Each Criterion

The score of each alternative has been indicated by each criterion in order to provide systematic determined the score. The process of determining the score of each alternative on each criterion has duplicated step from the above process.

Three alternative, included Bang Phra Kong (B), Lard Krabang (L) and Phra Pra Daeng (P), has been determined score on each criterion: Location, Cost, Capacity and F. The score has been illustrated in the following tables.

The pairwise matrix of each alternative toward the criteria of location, as first criterion, has been indicated and compute as the following table:

Table 31: Pairwise comparison matrix of location criterion

	B	L	p	Score
B	1	2	3	0.5247
L	1/2	1	3	0.3338
P	1/3	1/3	1	0.1416
λ_{max} = 3.0538		CI = 0.0269		CI/RI = 0.0464

From the above table (Table 31), weights of location criteria indicate the highest score on Bang Phra Kong, with 0.5247, following by Lard Krabang and Phra Pra Daeng, respectively, with the consistency ration 0.0464. This score has been shown the consistency, CR < 0.10.

The second criteria, cost, has also been indicated by pairwise comparison matrix. The computed score has been shown in the following table

Table 32: Pairwise comparison matrix of cost criterion

	B	L	p	Score
B	1	1/2	1/3	0.1638
L	2	1	1/2	0.2973
P	3	2	1	0.5390
λ_{max} = 3.0092		CI = 0.0046		CI/RI = 0.0079

The score of second criteria that has been computed as shown in the above table has shown the absolute contradictory result with the weight of location criteria. The highest score is relied on Phra Pra Daeng, with 0.5390, following by Lard Krabang and Bang Phra Kong, respectively. The consistence ratio is also illustrated the consistency with the score 0.0079, CR<0.10.

The capacity criteria has been identified the pairwise matrix and computed to specified weight of each alternative. The result has been shown in the following table.

Table 33: Pairwise comparison matrix of capacity criteion

	B	L	p	Score
B	1	2	2	0.4905
L	1/2	1	2	0.3119
P	1/2	1/2	1	0.1976
λ_{max} = 3.0537		CI = 0.0269		CI/RI = 0.0463

According to the computing weight of each alternative toward capacity of the warehouse criteria, the score has been illustrated that Bang Phra Kong obtain the highest score, 0.4905, and follow by Lard Krabang and Phra Pra Daeng respectively. The consistency ratio is 0.0463 that reinforce the consistent of this pairwise comparison matrix on the criteria of capacity, CR < 0.10.

The last criterion is infrastructure. The infrastructure criteria are quite equivalent score in each alternative. However, the pairwise comparison matrix has been built and computed the weight toward each alternative as shown in the following table.

Table 34: Pairwise comparison matrix of infrastructure criterion

	B	L	p	Score
B	1	1	2	0.3873
L	1	1	3	0.4429
P	1/2	1/3	1	0.1698
λ_{max} = 3.0183		CI = 0.0092		CI/RI = 0.0158

The highest score of infrastructure criteria is at Lard Krabang, with 0.4429 score and following by Bang Phra Kong and Phra Pra Daeng, respectively. Consistency ratio is 0.0158 that illustrated the consistency of the pairwise comparison matrix of this criterion toward all alternatives.

5.2.5 Calculation an overall score, determining the best alternative

According to calculate an overall score for each location, determining the scores of each alternative on each criterion has been summarized in the following table, in order to calculate the best alternative in this research.

Table 35: Summarized score of each alernative on each criterion

	Location	Cost	Capacity	Infrastructures
B	0.5247	0.1638	0.4905	0.3873
L	0.3338	0.2973	0.3119	0.4429
P	0.1416	0.5390	0.1976	0.1698

The final score of each alternative in order to determine the best alternative has been compute by combining the score of each alternative on each criterion with the weight of each criterion, w_i. The result of final score has been calculated and illustrated in the following table.

Table 36: Final score of each alternative

Overall Score	Bang Phra Kong	Lard Krabang	Phra Pra Daeng
	0.3965	0.3381	0.2654

According to the above table, Bang Phra Kong is obviously obtained the highest score in this research, with 0.3965 score, closely following by Lard Krabang.

Four principle criteria, including location, cost, capacity and infrastructure, have been taken into consideration so as to apply decentralized concept. The weight of importance has been illustrated that the company pays highest attention of location of new warehouse with 0.4909 score following by cost (0.2913), infrastructure (0.1507) and capacity (0.0670), respectively.

From this research, the overall final result illustrated that Bang Phra Kong is the best alternative for the company to decentralize the new warehouse. The company really concerns about location due to the disruption in order to diversify the risk and extend the capacity. Moreover, there are two motor way lanes, Bangkok-Chon Buri Motorway and Bang Na Chon Buri Expy. These two lanes are directly to Chon Buri and link to the Laem Chabang Port. The accessibility to the site is convenient in both from the factory to the site and the site to the agent premises.

However, the cost is also carefully considered because the company is SMEs that does not have a huge budget in order to find the really best premium one. The company is looking for an affordable and reasonable price with acceptable conditions. Although Bang Phra Kong is not offered the best prices, the condition and occurred cost is still acceptable by the company. Flood disruption is one of the most important factor that cause leasing price in this zone is increasing due to various manufacturers in many sectors have been invested and extended their production line into this zone.

Infrastructure is another criterion that Bang Phra Kong does not obtain the highest weight, as second best followed Lard Krabang. However, the overall fundamental equipment for warehouse operation, which is efficient and sufficient for the operation, is provided.

Capacity is another criterion that obtains the highest score. The company is not only concerned about current capacity, but also the flexibility of the usage area for the future expansion of the surrounding area. The flexibility is concerned about regulation to usage the area in that zone. Even all three alternatives situated in the industrial zone, Bang Phra Kong is the most flexibility in usage area for the future expansion because of lower density of industry and community in comparing with other two alternatives. Due to Phra Pra Daeng is located in Samut Prakan; this area has high density of the industry because it is adjacent to Bangkok. There is no room for expansion. Lard Krabang is quite close to the Suvarnabhumi airport as well as international container depot (ICD). This also means that communities have been grown up around this area, which could be a big problem for the future expansion.

Chapter 6 Conclusion and Recommendation

Disruption in the supply chain has been considered as an unpredictable incident that can caused a huge damage and impact in the supply chain as well as economic. While the globalization outsourcing, OEM, has been widely applied in order to minimized cost, JIT and lend practices have been operated as to reduce the excess inventory in each node along the supply chain as well as minimize cost of holding inventory. Moreover, centralized distribution and producing is also concerned as convenient and lower costs. These practices have been currently realized that caused supply chain vulnerability.

The research has illustrated that the company, as case study, has been damaged and loss from the supply chain disruption, as flood in Thailand, due to being a part of these practices. The company's initial perception about systematic inventory management and distribution planning are necessary only for big firm, which has higher production volume and wider distribution network. The company, as OEM, has a monthly fixed contract of delivered quantity and fixed agent in distribution. Therefore, these may not necessary to the company.

Therefore, the research has been introduced the fundamental practice in supply chain as a mile stone to the company in order to redesign supply chain operation for increasing the resilience and mitigate risk from the disruption by divided into two parts so as to deal with the disruption; propose safety stock level and decentralized warehouse to diversify the risk.

Firstly, propose safety stock level. The company applies JIT system in its lean production, keeping zero inventory stock in the system of both finished goods and raw materials, due to squeezing cost. The principle of inventory management has been ignored and unrecognized, obviously concept of safety stock. The company relies on experience to deal with the inventory flow. During the disruption, the company indirectly gains impact from run out of stock; raw materials that in the production line and finished goods that flow out to the customer.

The fundamental safety inventory calculation has been recommends instead of unsystematic estimating the inventory flow and manual control. Three scenarios of safety stock of both finished goods and raw materials have been displayed in comparing with different service level; 95%, 97% and 99% in both normal distributions in 2010 and disruption in 2011. Each item has been selected in variety of safety stock levels due to item condition of each item.

Secondly, decentralize warehouse by AHP model. The company applies centralization of distribution and production in order to minimize cost. All raw materials would be directly delivered to the factory, while finished goods are also stored and distributed from the factory to the agent premise. During the disruption, lot size of finished goods is not able to deliver to the agent premise because of lack of logistics accessibility to the agent premise.

AHP model has been introduced to assist in multi objective solution of selecting the best warehouse to be decentralized. Three locations have been proposed with four main criteria. Besides diversify risk of distribution by decentralized new warehouse in the network as a major reason, another reason is storage spaced requirement. The result illustrate that Bang Phra Kong is the best alternative in this case.

Moreover, the overall aspect of inventory management as well as distribution network planning have to be considered in the next stage in order to find out the optimal risk resilience mitigate risk of disruption in the supply chain.

Nevertheless, supply chain disruption management is not able to be concerned by sole company, the total supply chain stakeholders have to be involved in the holistic view such as increasing alternative sourcing, increasing collaboration with suppliers or implement a more robust risk assessment process, in order to create business continuity, which is the utmost goal of the supply chain risk management.

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