WAREHOUSE SYNERGY: A CASE STUDY IN PTT

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เนื่องจากว่า ณ ปัจจุบันนี้ โกดังเก็บสินค้าของกรณีศึกษาได้มีการปฏิบัติงานแยกกันโดยชัดเจนและมีพื้นที่เหลือค่อนข้างมากในแต่ละที่ จุดประสงค์ของวิทยานิพนธ์ฉบับนี้คือหาแนวทางที่จะสามารถเพิ่มผลประโยชน์ให้กับกรณีศึกษา โดยหลังจากที่ทำการพิจารณาแนวทางการพัฒนาศักยภาพทางด้านโกดังเก็บสินค้าหลายๆแนวทางแล้ว พบว่าแนวที่ดีที่ที่สุดที่เหมาะสมกับกรณีศึกษาคือ การปิดโกดังเก็บสินค้าบางส่วนลง ดังนั้นหลักเกณฑ์และวิธีการคัดกรองเพื่อประเมินโกดังเก็บสินค้าจึงได้ถูกกำหนดขึ้นและได้ถูกเรียกว่ากระบวนการคัดกรองโกดังเก็บสินค้า ซึ่งกระบวนการคัดกรองโกดังเก็บสินค้านี้ได้ถูกจัดทำโดยยึดตามความรู้ทางวิชาการประกอบด้วยข้อมูลจากทางกรณีศึกษาเพื่อให้ได้แนวทางการพัฒนาที่เป็นไปได้

ในขั้นตอนการคัดกรองโกดังเก็บสินค้านั้นมีด้วยกัน 5 ขั้นตอนได้แก่ การคัดกรองโดยนโยบายและข้อจำกัด, การประเมินประสิทธิภาพและค่าใช้จ่าย, การสร้างตัวเลือกสำหรับการคัดกรอง, การประเมินความเป็นไปได้ในเรื่องของพื้นที่เก็บสินค้า, และการวิเคราะห์ทางเลือกที่ถูกเลือก โดยหลังจากดำเนินการตามกระบวนการที่เสนอไปนั้น ทางเลือกที่ดีที่สุดสำหรับกรณีศึกษาได้ถูกเลือกขึ้นซึ่งสามารถให้ผลประโยชน์กับกรณีศึกษามากที่สุด โดยสามารถลดค่าใช้จ่ายในการปฏิบัติงานในโกดังเก็บสินค้าลงถึงประมาณ 100 ล้านบาทต่อปี ซึ่งผลสรุปของวิทยานิพนธ์ฉบับนี้ได้รับการตรวจสอบจากกรณีศึกษาเป็นที่เรียบร้อยแล้ว

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At present, the case study companies operate their warehouses independently and also face with the low utilization of capacities. The objective of this thesis is to find the way to improve benefits in the case study companies. After analyzing through the choices of improvement in warehousing area, the most suitable option for the case study companies is to phase out some of the existing warehouses. Therefore, the criteria and the screening process used for evaluate the warehouses must be specified and so called warehouse phasing out process. The warehouse phasing out has been developed based on the academic knowledge and the case study companies data in order to create the feasible solution.

There are five main steps in phasing out process which are listed as follows: policy and constraint screening, performance and cost evaluation, phasing out alternatives development, capacity feasibility evaluation, and final analysis of chosen alternative. After implementing the proposed process, the best alternative has been selected since it gives the best benefits to the case study companies. The operation costs can be reduced around 100 million Baht per year after implementing. This result has already validated from the case study company.

Department : Regional Centre for Manufacturing System Engineering Student's Signature .....
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CHAPTER I

INTRODUCTION

1.1 Background of the Thesis

Nowadays, the competition is increasing all over the world in every business. Most companies have to enhance its performance to strive to be competitive in the business. These and other challenges force companies to almost continuously analyze and re-consider their supply chain networks, striving for efficiency and improved responsiveness (Angel et al., 2006).

According to Bowersox and Daugherty (1996), escalating competitive pressures and increased performance requirements have resulted in greater recognition of the importance of logistics activities. Since logistics costs are steadily growing and accounted for the main cost in many companies, the improvement of logistics functions will help enhancing the performance of those companies. Logistics costs have become an important part of the added value of products and logistics management is increasingly regarded as an important weapon in the international competitive struggle, in particular by large market-oriented companies (Dick and Marinus, 1996).

There are many processes which affect to the logistics costs. The one involved in logistics functions is warehouse. Warehousing strategy is an essential element of the overall distribution logistics strategy and especially the decision of selecting optimal sites for warehouses has significant effects on customer service and logistics cost (Jukka and Markku, 1996).

Faced with increasing competition and mounting cost pressures, a growing number of firms are considering re-configuring or re-engineering their corporate structures through the consolidation and phase-out of some of their existing warehouses (Emanuel Achille, and Hokey, 2005). Rationalizing the existing warehouses will help enhance the performance of the company. As Prabir and Targe (1995) stated that leading

companies are rationalizing their logistics systems in Europe leading to consolidation in manufacturing and logistics facilities.

The transitions underlying some of the mega-trends represent the challenges of the emerging decade for logisticians and supply chain executives and identify the direction for change. These mega-trends imply substantial change in logistics practices between supply chain partners as they struggle to establish efficient, effective, and relevant product/ service solutions for end-customers. Adversarial to collaborative is one of the ten mega-trends. The notion of focused collaborative arrangements, coupled with true cradle to grave accountability, is revolutionizing the way that firms work together to streamline the distributive process. The potential for increased overall efficiency as a result of reduced work duplication and redundancy are astounding (Bowersox, Closs, and stank, 2000).

From the situation mentioned above, PTT public company who is considered to be one of the biggest petroleum businesses in Thailand sees an opportunity to create an optimization and increase the level of efficiency in its logistics operations to cope with the competition increased nowadays and also the aspiration to be in Fortune 100 in the next five years.

1.2 Background of the Case Study Company

PTT public company limited (PTT) has four main units which are gas, oil, international trading, and refinery and petrochemical unit. This thesis will cope with the petrochemical unit only due to the fact that the studied warehouses are the plastic resin warehouse.

Petrochemical group of PTT is the biggest in the country and ranks among the top in Asia. The attempt to improve the company is continuously done to keep the rank. The management of PTT is the one who has inspired the aspiration of the company and also thought that there might be a gap to be improved in logistics issue.

There are 4 companies involved which are PTT Chemical Public Company Limited (PTTCH), IRPC Public Company Limited (IRPC), PTT Polymer Logistics Company Limited (PTTPL), and HMC Polymers Thailand (HMC) operating the solid polymer warehouses by themselves.

Three of them also own the production plants manufacturing the same type of product which is plastic resin. However, there are variety of plastic resins exist such as Poly Ethylene, Polypropylene, Polystyrene, and Acrylonitrile butadiene styrene (ABS). The variety of plastic resins has no effect to the warehouse due to the fact that they can be stored together. The warehouses of these three companies are only used to store their products only while PTTPL who is the logistics provider services the company in PTT group is giving the service to PTT group companies.

These companies are the subsidiaries of PTT so PTT has an authority to decide the main strategy for the group due to the fact that PTT is the main shareholder in all of the four companies.

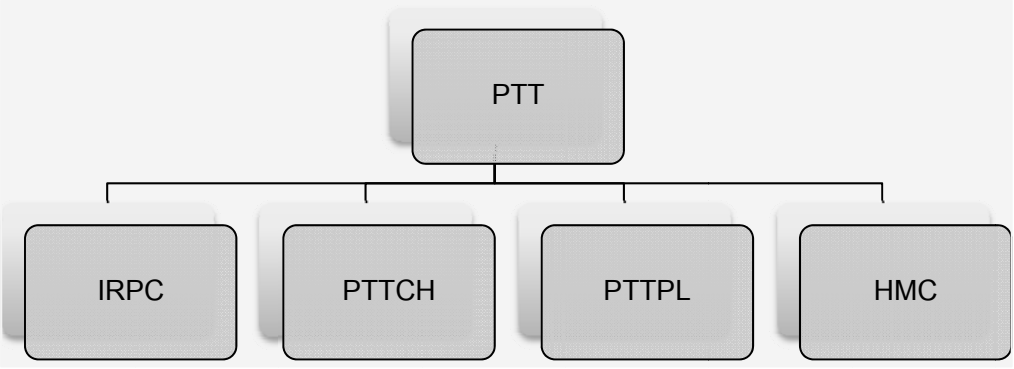


Figure 1.1: Case Study Company Structure

There are 11 warehouses storing plastic resin products in these companies as illustrated in the figure below.

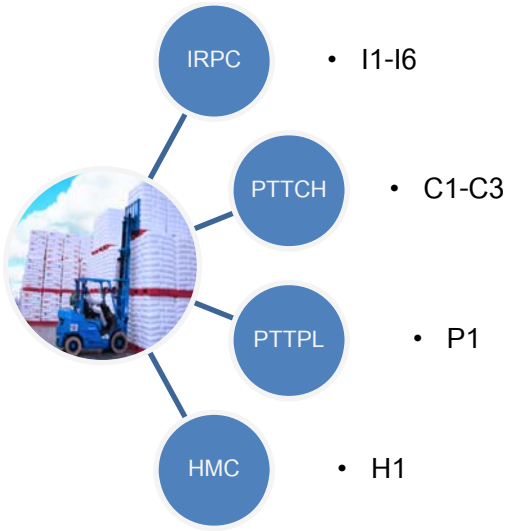


Figure 1.2: Warehouses in PTT Group

Each company has different number of warehouse owned and stores individually. PTT which is the mother company of these four companies had not looked at the whole picture of managing the same type of warehouse until now since there is an increasing of competition all over the world including Thailand so PTT is now considering to rational the existing warehouses in order to improve the overall benefits. Prabir and Targe (1995) stated that companies with multiple facilities, both manufacturing plants and distribution warehouses, in various countries are likely to consolidate activities in fewer plants and warehouses. This thesis is then developed to create the plan for PTT in warehousing area to improve the benefits.

The table below shows the details of each warehouse in each company including the name of the warehouse, the type of the warehouse, the capacity of the warehouse, the capacity occupied in 2010, and the excess capacity. The capacity of the warehouse in this place is the total weight of each warehouse that can store the products in any time. Weight of the product in this thesis can be used to determine capacity of the warehouse because the major polymers stored in the warehouse have density around 1 g/cm^3 which means that the weight can replace the volume in this circumstance.

Table 1.1: Warehouse Details

Company	Warehouse	Type of W/H	Capacity (Tons)	Capacity occupied in 2010 (Tons)	Excess capacity (Tons)
IRPC	I1	Manual	34,309	9,762	24,547
	I2	Manual	33,415	12,821	20,594
	I3	Manual	1,060	1,463	(403)
	I4	Manual	16,790	7,315	9,475
	I5	Automatic	50,208	12,584	37,624
	I6	Automatic	40,320	5,632	34,688
PTTCH	C1	Manual	20,406	10,189	10,217
	C2	Manual	18,320	5,154	13,166
	C3	Manual	4,700	2,206	2,494
PTTPL	P1	Manual	80,000	25,835	54,165
HMC	H1	Manual	8,500	5,193	3,307
Total			308,028	98,155	209,873

Comparing between the capacity of each warehouse and the capacity occupied gains the excess capacity of warehouse that considered to be over and costs a lot of money. The capacities of 209,873 tons are available at the moment. However, HMC is now renting external warehouse for storing their products concurrently with warehouse H1 also. The capacity occupied in the external warehouse is 7,297 tons. Therefore, the total excess capacity in 2010 is 202,576 tons.

1.3 Statement of Problem

Logistics is considered to be the main obstacle in driving PTT into Fortune 100 since the cost of logistics in PTT is quite high. In PTT group business, petrochemical business is growing very fast together with the higher cost of warehouse operation. An estimated cost of warehouse in 2016 will be around 795 million Baht compared with 332 million Baht in 2009. The major reason is believed to be an independent operation among the affiliates of PTT called PTT group companies and the low utilization of warehouse capacity.

There are many companies in PTT group that operate in the same business and also do the same activities at the same time. However, these companies are currently operating independently without any coordination or collaboration. Even if each individual firm in such a chain is performing integrated logistics management of its own internal operations, there still exists a great potential to increase the overall efficiency as a whole by practicing integrated logistics management on the total flow of material throughout the entire supply chain (Bernard and James, 1994). Thus, the collaboration between these companies might give better benefits to both PTT and PTT group companies.

The capacity of warehouse used in the year 2010 was lower than 50% of the total capacity. The excess capacity was unoccupied which costs a lot of money in warehouse operation area.

From the problem mentioned above, this thesis is developed to find the way to improve warehousing area in PTT Group as an aggregation plan based on the idea of warehouse space synergy among the companies in PTT group.

1.4 Thesis objective

To improve benefits on total warehouse costs occurred in PTT group solid polymer given by an establishment of warehouse space synergy.

1.5 Scope of the thesis

- The interested area of warehouse in this thesis will be coped with the warehouses of plastic resin of PTT group companies which are IRPC, PTTCH, HMC, and PTTPL.
- There will be no further investment in constructing new warehouse in this thesis.
- There will be no external renting choice in developing alternatives due to the policy of PTT. PTT is trying to do warehouse synergy among the companies in PTT group trying not to pay its money out of the group.

1.6 Methodology

1.6.1 Exploratory research from literatures, books, and journals

This phase focuses on researching relevant literatures, books, and journals about the performances and costs of the warehouse, the evaluation method of warehouses, and the design of the cost model. Data from the research will be analyzed and identified to set a scope and arrange a schedule for the thesis. The objective of the thesis and its expected benefit are also settled in this phase.

1.6.2 Collect all related information from the case study companies

There are three main data that will be collected from the case study companies which are policies and constraints of the warehouse, performances of the warehouse, and cost elements in warehouses.

1.6.2.1 Policies and constraints

The policies of the case study companies about the warehouse and the constraints in warehouse sharing will be identified. This information will help eliminate alternatives that cannot be implemented in the real situation.

1.6.2.2 Performances of the warehouse

The performances including the utilization of each warehouse will be collected. The examples of performance indicator are the amount of damage product, safety level, accuracy, and customer satisfaction.

1.6.2.3 Cost elements in warehouses

There are many costs that related to the warehouse operation. These related costs will be studied and collected to make the evaluation precise as much as possible. The precision of evaluation will affect to the alternative chosen.

1.6.3 Develop the alternative solutions

All the feasible alternative solutions of warehouse synergy among PTT group companies will be developed. The screening process also established in order to eliminate an unnecessary or impossible solution.

1.6.4 Determine the benefits occurred

The reduction of cost from establishing warehouse synergy will be determined case by case. The cost will include related warehouse operation costs, the warehouse charges, and also the transportation costs to determine the benefit gained in term of cost saving.

1.6.5 Analyze and conclude

The best alternative will be illustrated and concluded. Also, the discussion on the alternative compared to the existing warehouse operation in the case study companies is provided.

1.7 Research Schedule

Table 1.2: Research Schedule

	Jun 10	Jul 10	Aug 10	Sep 10	Oct 10	Nov 10	Dec 10	Jan 11	Feb 11	Mar 11	Apr 11	May 11	Jun 11	Jul 11	Aug 11
1. Study research															
2. Collect data															
3. Develop the alternative solutions															
4. Determine the benefits occurred															
5. Summarize															

1.8 Expected Benefit

1) Performance of each warehouse will be analyzed based on the theory and the case study information.

2) The various alternatives will be invented. These alternatives will be developed based on the possibility of the real implementation.

3) The benefits from warehouse synergy in each alternative will be analyzed.

4) Lastly, the best alternative that gives the maximum benefit to PTT will be chosen.

CHAPTER II

PROBLEM DESCRIPTION

Managing warehouse is not a short-term decision, but it is a long-term decision. The main function of warehouse is to store the product. Therefore, evaluating the demand of products to be stored in the warehouses in the future is essential. Due to the fact that the plan in this thesis is a five-year plan, the demand of products in 2015 is needed.

2.1 Problem Analysis

Table 2.1: Expansion Plan

Company	Expansion Plan	No. of Project	CAPEX
			THB million
PTTPL	X	-	-
PTTCH	X	-	-
IRPC	✓	7	54,048
HMC	✓	1	224
Total		8	54,272

From the table above which shows the expansion plan of PTT group companies in the next five years, there are only two companies from four that have the plan to expand its asset. One is IRPC and one is HMC. The project of HMC is involved with the silo which considered not related to the scope of this thesis. However, there is one project of IRPC that has to be considered which is ABS expansion project. IRPC currently produces ABS with the capacity of 117,000 tonnes per year and it intends to increase ABS production capacity by 61,000 tonnes per year to support the production of special grade ABS which has higher market demand. This project is scheduled for completion and commercial production in 2013.

2.2 Business Growth

The forecasted sale volume of products is done by PTT and translated into the percentage of product growth for each company. This volume has included the expanded volume of products already.

Table 2.2: Growth rate in 2015

Company	Growth rate in 2015
IRPC	5%
PTTCH	34%
HMC	47%
PTTPL	61%

The sale volume affects the capacity of the warehouse. The more volume of products, the more capacity of warehouse needed. However, the capacity of warehouse also depended on the inventory turnover ratio which is an indicator determining how quickly a warehouse turns over its inventory (Joyce and Wood, 2001). Levi and Kaminsky (2003) proposed the equation for evaluate the inventory ratio as followed.

$$\text{Inventory turnover ratio} = \frac{\text{Annual sales}}{\text{Inventory level}}$$

From the historical data of PTT, we acknowledge the inventory turnover ratio of each warehouse in 2010. The inventory turnover ratio is the ratio showing how fast the inventory turned. The higher the number of ratio is, the fast the warehouse turns. The fast the warehouse turns, the more the space of warehouse available. It is depended mostly on the relation between the production and the sale direction of the company, and the characteristics of products that stored in each warehouse. The inventory turnover ratio in each warehouse in 2010 is then assumed to be the same in the year 2015 since the direction of the company is to try to make the inventory turnover ratio constant. In addition, the production direction in the future will be a made-to-order more than a made-to-stock so the trend of the inventory turnover ratio will be increased.

Due to the fact that each warehouse has different capacity and different turnover rate, the ability to store the product is not equal. The future inventory level in 2015 is then evaluated by the annual sales in 2015 divided by the inventory turnover ratio. The annual sales in 2015 are the sale volume of each warehouse multiplies the growth rate of the product.

The evidence of an excess capacity is shown in this place. The capacity of 170,988 tons from PTT group companies is the excess capacity after evaluating the future demand. This amount of excess capacity is the capacity that is unoccupied which costs a lot of money. Therefore, this thesis will provide a solution to solve this problem in order to gain the better benefit for PTT. The solution of improving the warehousing area in PTT Group will be proposed.

Table 2.3: Inventory level in 2015

Warehouse	Capacity	Annual sales in 2010 (Tons)	Forecasted annual sales in 2015 (Tons)	Inventory turnover ratio	Inventory level 2010 (Tons)	Forecasted Inventory level 2015 (Tons)	Excess capacity in 2015
I1	34,309	117,356	123,224	12	9,762	10,250	24,059
I2	33,415	128,241	134,653	10	12,821	13,462	19,953
I3	1,060	7,537	7,914	5	1,463	1,537	(477)
I4	16,790	294,024	308,725	40	7,315	7,681	9,109
I5	50,208	183,241	192,403	15	12,584	13,213	36,995
I6	40,320	132,229	138,840	23	5,632	5,913	34,407
C1	20,406	279,887	375,049	27	10,189	13,654	6,752
C2	18,320	272,673	365,382	44	6,185	8,288	10,032
C3	4,700	45,103	60,438	20	2,206	2,956	1,744
P1	80,000	333,237	536,512	13	25,835	41,594	38,406
H1	8,500	58,108	85,419	11	5,193	7,765	735
EXT		29,188	42,905	4	7,297	10,726	
Total	308,028					137,040	170,988

2.3 Common Improvement in Warehousing Area

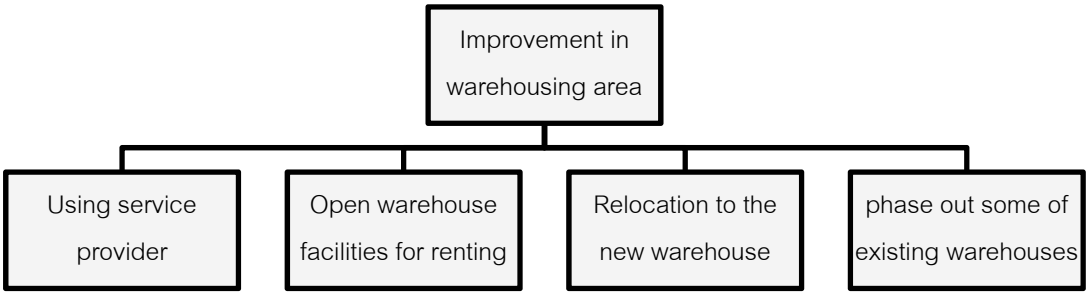


Figure 2.1: Improvement in Warehousing Area

There are four main common decisions in improving warehouses which are using service provider, open warehouse facilities for renting, relocation to the new warehouse and phase out some of existing warehouses. According to Melachrinoudis, Messac, and Min (2005) and Dornier et al. (1998), they proposed the way to overcome an increasing of competition and mounting cost pressures by consolidating and phasing out some of the existing warehouses. Open warehouse facilities for renting is another option proposed by Korpela and Tuominen (1996) as they stated that owning warehouse facilities is not the only option for organizations in need of storage space as warehouses can also be leased or rented. Excess capacity of existing warehouses can be used to gain benefits instead of leaving it useless. Relocation of warehouse is also presented in a real-world case study of warehousing area as seen in Melachrinoudis and Min (1999) which may create better benefit to the company more than the present circumstance. The last one is using service provider which is now considered to be popular (Bagchi and Larsen (1995) and Krakovics et al. (2008)).

2.4 Suitable Improvement for PTT

Four main improvements in warehousing area will be analyzed in this section in order to select the best suitable solution for PTT.

2.4.1 Using Service Provider

Outsourcing logistics activities could reduce the investment in assets, while increasing operational flexibility and allowing greater focus on the core activity of the business, in addition to reducing costs, and improving the quality of service provided (Fabio et al. 2008). Nevertheless, one of the reasons that PTT had a warehouse synergy project is that they want to keep the money circulated internally. Instead of paying rental fees to the external company, paying rental fees to one of the PTT companies are much better.

2.4.2 Open Warehouse Facilities for Renting

Open warehouse facilities for renting sounds attractive for PTT since they do not have to change anything except finding the renter. However, finding the renter is not easy in Maptaphut area due to the fact that there are many companies who are specializing in servicing warehouse now operating. No renter means excess warehouse capacities leave useless and the costs of operating warehouse still exist. Furthermore, servicing in warehouse is not the core competency of PTT.

2.4.3 Relocation to the New Warehouse

According to the policy of PTT, they do not want to invest in the new warehouse. Therefore, this option has to be eliminated. Moreover, there are three main factors of relocation decisions are cost, traffic access, and local incentives as shown in Melachrinoudis and Min (2000). Total transportation costs can be reduced, due to increased opportunities for large-volume shipments (Melachrinoudis, Messac, and Min (2005). However, only full truck load is sent out of the warehouse in case of PTT group companies so the saving may not occur. Most of the plants and warehouses are situated in Maptaphut, Rayong which located near the plant. Therefore, the problem of traffic

access does not happen. The local incentive for the new warehouse is not going to happen due to the fact that the new warehouse will be situated near the old warehouse. In addition, the information needed in formulating the new warehouse and the benefits cannot be found. The selection process in selecting an appropriate area of the new warehouse and the investment cost have to be included which considered which not considered to be a part of this thesis.

2.4.4 Phase out Some of Existing Warehouses

In phase out some of existing warehouses, optimal number of warehouse will be placed resulting in lower costs from stop operating unnecessary warehouses. In Melachrinoudis, Messac, and Min (2005), they said that the fewer the warehouses, the longer the distances from customers. Nevertheless, this issue is not going to have an effect in PTT since the distance among PTT group companies is not far. The main disadvantage of this option is that if the demand of storing products is more than the capacity, PTT has to rent external warehouse. However, the five years forecasting had been done before in order to ensure that this capacity can be support PTT in the future. Therefore, phase out some of existing warehouses is considered to be the best option for PTT.

2.5 Phase out some of existing warehouses

In general, the problem of locating manufacturing (or warehousing) facilities is concerned with the determination of the optimal number, size, and geographic configuration of those facilities in such a way as to minimize the total cost associated with supply chain operations (e.g. start-up investment, material acquisition, transportation, storage and production cost), while satisfying customer demand requirements (Melachrinoudis and Min, 1999).

The objective of this work is to create the better benefits in warehouse area for PTT. Benefits include tangible and intangible benefits. The main thing to do is to close some of the existing warehouses in order to meet the optimum capacity. High performance

warehouse should not be closed since it usually gives higher benefits and lower costs to the company. Due to the fact that there are excess capacities that considered being useless to the PTT group which cost a lot of money, one way to accomplish this problem is to stop operating low performance warehouses with the optimal capacity.

Hence, the way to manage an over capacity problem is to close some of warehouses. The existing warehouses of PTT are 11 warehouses. To close or open any of these warehouses, alternatives should be developed to help determine which alternative gives the best benefits to PTT. However, screening process should be done before developing alternatives to screen some types of warehouse.

CHAPTER III

CONCEPTUAL DESIGN FOR WAREHOUSE PHASING OUT PROCESS

The most appropriate choice to improve the warehouses in PTT Group has been specified from the previous chapter. This chapter will then describe how to design the process of phasing out the warehouse as the concept.

3.1 Common Screening Criteria

We note that the majority of warehouses suggested for phase-out or relocation are either underutilized, or have low intangible benefits and high costs. It is also interesting to note that most of the retained warehouses, including the consolidated ones, are either at the center, or in the vicinity of the center of concentrated demand locations (Melachrinoudis, Messac, and Min, 2005). Miller (1956) observed that an ordinary decision maker could not handle more than 7 or 9 decisions elements (e.g. criteria and alternatives) simultaneously without being confused. Six broad categories are used for ranking the warehouse site: site characteristics, cost, traffic access, market opportunity, quality of living, and local incentives (Melachrinoudis and Min, 1999). Traditionally, an optimal distribution network is yielded by allocating customer orders to warehouses so that the total logistics cost is minimized while the warehouse capacity constraint is not violated (Ho, 2007). Ballou (1981) defines the key decisions areas in logistics system design as policy, location, and transport selection/routing.

The table below compares the criteria used in warehousing area among different literatures.

Table 3.1: Criteria Used in Various Literatures

Melachrinoudis, Messac, and Min (2005)	Melachrinoudis and Min (1999)	Ho (2007)	Korpela and Tuominen (1996)
Cost Location Capacity Intangible benefits	Cost Location Site characteristics Market opportunity Quality of living Local incentive	Cost Capacity	Location Policy Transport routing

Capacity, cost, and location are the criteria that used by more than one literature which indicates the importance of these criteria in common warehousing area. However, selecting suitable criteria for one process is depended on the objective of that process. Understand the objective of the process will help selecting the suitable criteria. Not every criterion is suitable for every process.

3.2 Screening Criteria for PTT

Selecting criteria for PTT is essential due to the fact that these selected criteria will be the key factor seeking for the proper alternative. The main three criteria which are capacity, cost, and location are the common criteria used for evaluating warehouse which should be included in the screening process for evaluating the warehouse in PTT also. In addition, the reason using these three criteria and other criteria that consistent with the case study company also provided.

3.2.1 Capacity

From the beginning, PTT has faced the problem of an over capacity in their warehouses. The main concern is that there are many spaces in the warehouses unoccupied. According to the study, the suitable way to help improving warehousing area in PTT is to phase out some of the existing warehouses. However, closing the warehouse has to be coped with the capacity in the future also. Therefore, the capacity is considered to be one of the important factors in the screening process.

Carles (2001) had shown the importance of analyzing the rate of usage. They stated that it is very useful to build a table indicating the degree of utilization of all those concepts for which it is possible to analyze their rate of usage. When we know how much resources we have, we can manage them efficiently.

3.2.2 Cost

Cost is considered to be one of the main performance criteria in the study area of warehousing. Since most of the companies establish for seeking for profits, one way to receive higher profit is to lower the cost. Moreover, there is an increasing of competition nowadays especially in term of cost. PTT has to find the way to improve their process in order to compete in the market successfully.

3.2.3 Location

Almost every literature brought here picked the location as the decision criteria. Location has significant effect to the benefits the company will receive due to the fact that different location means different cost of transportation. Especially in case of PTT, IRPC warehouses are situated at Cherngnern while others are situated at Maptaphut so there will be a difference in cost of transportation certainly.

Location is a criterion that considered to be hardly evaluated. However, location can be represented by the difference in cost of transportation. Different location means different transportation cost. This criterion has to be analyzed after passing all criteria since it needs the transfer analysis first. Before reaching this step, the certain

numbers of warehouses in each alternative and the destination warehouse of the closed warehouses have to be defined. Therefore, the location criteria will be analyzed concurrently with the benefits in each alternative.

3.2.4 Performance

The screening process has an objective to screen for the high performance warehouses with optimum capacity. As stated in the objective, performance is the key factor to be screened. Since this project involves with the warehouses from different company and different management, the performance of each warehouse will not equal. Furthermore, there is a literature that used performance as a key criterion which is from the work of Melachrinoudis and Min (1999). The performance should be evaluated in order to know the ability of each warehouse.

3.2.5 Policy and Constraint

This warehouse project is involved with 11 warehouses from four different companies. Even though they are in the same group which is PTT Group, they still have their own strategy or direction. To close some of their warehouse should not oppose with their strategy or constrain. Therefore, assessing policy which includes constrain will help creating the possible solution for PTT.

3.2.6 Other Criteria

Market opportunity, quality of living, and local incentive are not determined in this thesis due to the fact that these three criteria are similar with each other. The warehouses of PTT group are in the same province so the result of these criteria should be the same. Transport routing is not included in the scope of this thesis. Selecting which type of truck or which route should be used. Korpela and Tuominen (1996) was considering about transport routing because their scope was logistic system while the scope of this thesis is only warehouse area. For intangible benefits, it considered to be evaluated quite hard due to the fact that there are various types of intangible benefits. However, some intangible benefits will be analyzed in the analyze section.

From the discussion described, four main criteria in screening process aided to reach the objective are proposed.

1) Policy and constraint
2) Performance and cost
3) Capacity
4) Location

The warehouses of PTT will be screened from the overall image into the detail or the strategic level to the operational level as shown in the figure below.

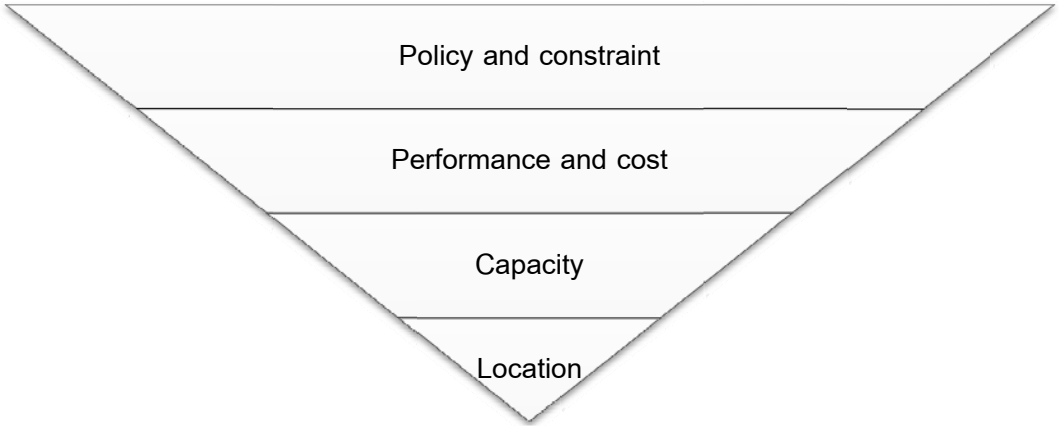


Figure 3.1: The Main Criteria of Evaluating PTT Warehouses

The reasonable way is to evaluate the warehouse in various criteria by evaluating step by step since the four criteria used to evaluate the warehouse have different meaning and different measurement method. There are two main measurements which are qualitative and quantitative measurement. The result of quantitative measurement is illustrated in form of number which can be evaluated and compared easily while qualitative is not. Policy and constrain in this place is considered to be the qualitative measurement while others can be converted to be the quantitative measurement. Furthermore, the priority of each criterion is not equal. Policy and constrain are consider to be in the strategic level while performance and cost are considered to be in the operation level which is hard to be evaluated at the same time. Nevertheless, all criteria might be converted to be in equation which can measure at the same time. However,

converting the information might create an error more than not converted. Evaluation of these four criteria step by step should create an exact result more than evaluation at the same time.

3.3 Screening Process

The problem when there is more than one factor is that it needs process to arrange and combine them. This thesis proposes the screening process which combines those four factors to screen the warehouse before developing alternatives. There are 5 steps in the screening process as described below.

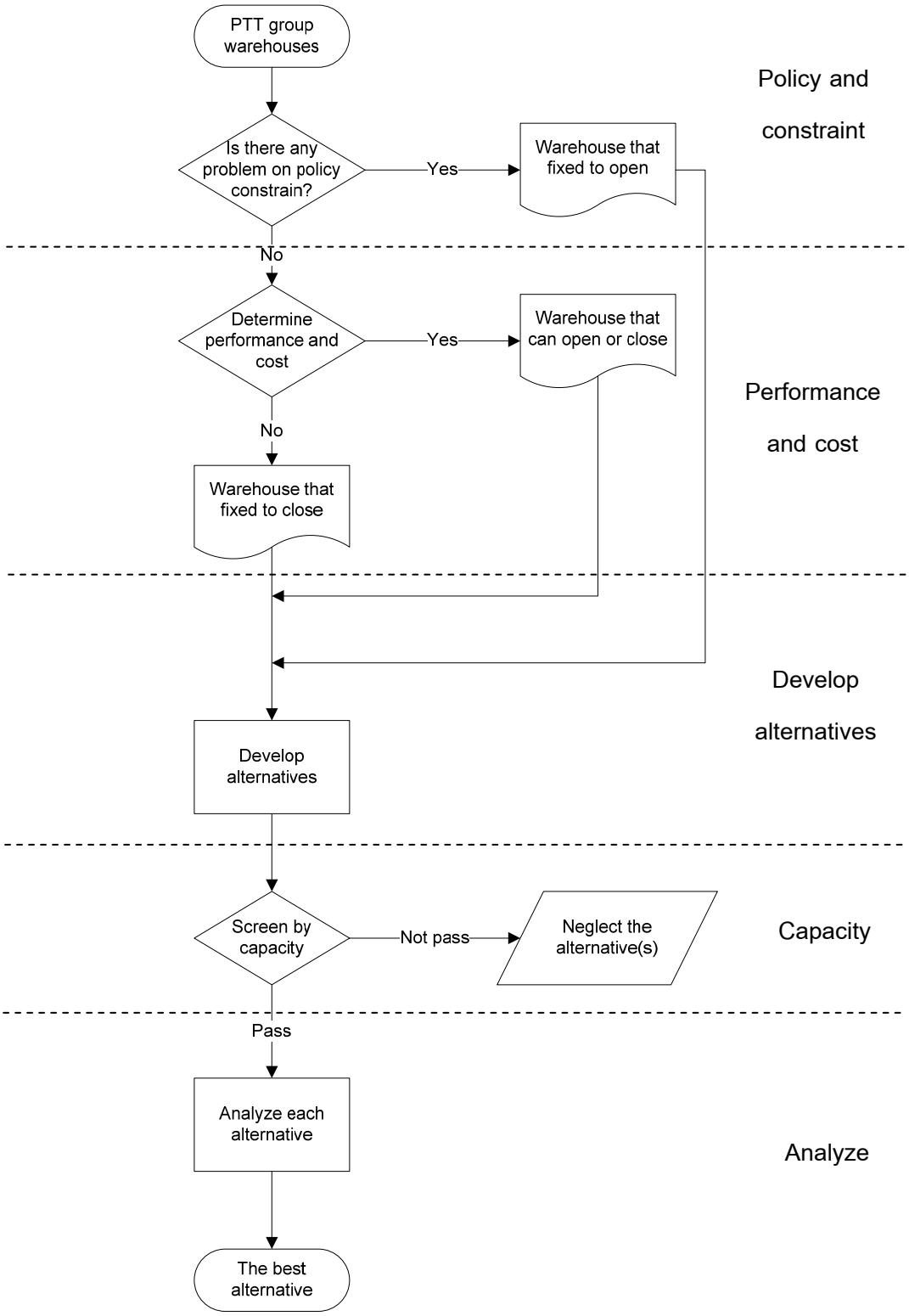


Figure 3.2: The Screening Process

3.3.1 Screening Process: Policy and Constraint Step

Property A has the more desirable ceiling height and square footage than property B. On the other hand, property A seems to be more costly option than property B in the long run. Therefore, the final selection of these properties may depend on Alpha's lease, buy, or re-building decisions. (Melachrinoudis and Min, 1999)

From the literature above, it shows that the company's decisions are more important than other factors. Screening by performance and cost can be done before the policy and constrain, but it has no reason to do that since the warehouse that does not pass the performance and cost criteria but has some constrain to open so it has to be opened. Therefore, policy and constrain is the first criteria to screen the warehouse. However, there is no methodology in deciding about policy and constrain except the information given by the company.

After passing this step, there will be some warehouses that cannot be closed due to the policy and constraint of the company. Other warehouses that pass this step without trouble with the policy and constraint will be screened by the performance and cost further.

3.3.2 Screening Process: Performance and Cost Step

Performance and cost is the second criteria to be considered. This step will help evaluate every warehouse in order to acknowledge which warehouse has low performance and high cost warehouse by warehouse. The performance and cost will be illustrated in term of the score to see rank among these warehouses.

In evaluating performance and cost, there must be many factors used to evaluate performance and cost in each warehouse such as productivity and accuracy. Due to the fact that there are more than one criterion used in evaluating performance and cost, the methodology is then needed in order to gain the overall score in each criterion.

Since there are many criteria in evaluating warehouse, the method to evaluate is needed. Multi-criteria decision analysis (MCDA) is used to help decision maker to make the decision in the logical way. The MCDA is a dynamically developing research area that utilizes several evaluation criteria in choosing, sorting, and ranking of different alternatives (Vincke, 1990).

Among the discrete methods, also called multi criteria analysis (MCA) methods, the best known are the multi attribute utility theory, the analytic hierarchy process (AHP) and the outranking methods (Melachrinoudis, Messac, and Min, 2005). It is observed that AHP is being predominantly used in the area of selection and evaluation (Maggie and Tummala, 2001). AHP is often being used in warehouse selection because it allows decision makers to rank warehouse based on the relative importance of the criteria. The use of AHP is increasing with time as shown in figure 4.3.

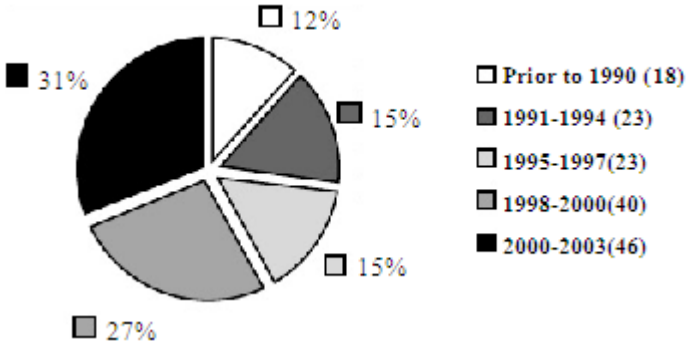


Figure 3.3: The Use of AHP over the Years (Omkarprasad, and Kumar, 2006)

AHP (Analytic Hierarchy Process) was used widely in warehouse selection which is a scoring method that was designed to visually structure a complex decision problem into a simple hierarchy and then develop priorities within each level of hierarchy (Melachrinoudis and Min, 1999). Thus, this thesis will use AHP as a main methodology to evaluate performance and cost.

After using AHP, the warehouses will be ranked in term of score. Amount of warehouses will be closed due to the low performance. The warehouses that passed this step will be used to develop the alternative.

3.3.3 Screening Process: Develop Alternatives Step

The warehouses that have no constraint against the company and have been qualified to pass the performance are then sent to be developed alternative. Developing an alternative has to be done before the screening by capacity. In each alternative, the detail showing which warehouse is closed or opened will be shown. Therefore, the overall capacity after changing can be determined.

The way to develop alternative is to create every possible choice. The number of alternative will depend on the number of the warehouses that have no constraint against the company and have been qualified to pass the performance.

3.3.4 Screening Process: Capacity Step

Capacity comes after performance and cost. This is because if performance and cost is not considered first, there will be too many alternatives created which are then screened out anyway because those alternatives will combine low performance and high cost warehouses with optimal capacity. According to the objective to select the best alternative that gives the best benefit to PTT, the alternative should be formulated by the high performance warehouses with the optimum capacity. Therefore, it is illogical to evaluate the capacity before performance and cost since it will create numerous alternatives that consist of low performance warehouses which will give low benefit to PTT. Moreover, redundant alternatives will create a complexity analysis.

Capacity in this place is calculated by the use of warehouse storage in 2015 divided by the total capacity of the new plan. Low utilization of the warehouse area will be screened out due to the fact that the more utilization rate of the capacity is, the more cost that should not be happened happen. The alternatives that screened out will be neglected while the alternatives that pass this step will be analyzed further.

3.3.5 Screening Process: Analyze Step

The alternatives will be analyzed in this step in terms of benefits providing to PTT. The best alternative that gives the best benefits to PTT will be selected. There will be many factors included in analyzing process such as operation cost and transport cost.

As seen in each alternative, there are two options for each warehouse which are close and open. For the close one, the products stored in that warehouse have to be transferred to the available warehouse within PTT group. Transport cost can be done only when the transfer is created.

The benefits will be analyzed in the quantitative method. The total cost in each alternative will be illustrated.

After implementation according to the flow, the better benefits will certain happen due to the fact that PTT will select the best alternative that had screened out low performance warehouses and also created high costs with the optimum capacity.

CHAPTER IV

WAREHOUSE PHASING OUT PROCESS

According to the conceptual design described in the previous chapter, more details that will give the clearness in each step of developed process will be provided in this chapter. Phasing out some of existing warehouses is chosen to be the path towards the objective of improving warehousing area in PTT group. Therefore, the details in screening process will be illustrated and described in this chapter.

From the conceptual design, there are 5 steps in the screening process which are policy and constraint, performance and cost, develop alternatives, capacity, and analyze. After passing these steps, the alternative that gives the maximum benefit to PTT will be provided. Therefore, the detail composed in each step is essential. The details mentioned before are described as followed.

4.1 Policy and Constraint Step

Policy and constraint is the first step in the screening process. The information about the policy and constraint is given by four companies which are IRPC, PTTCH, PTTPL, and HMC. There is no methodology to judge in this step except the information given by the companies. Therefore, the details involved with the policy and constrain will be described below.

4.1.1 IRPC Warehouse

IRPC is now considering closing some of their warehouse due to the fact that they have reviewed that they have too many warehouses comparing with the demand for storing their products which are not necessary and continuously create costs. The direction of IRPC is consistent with PTT project to re-structure all plastic resin warehouses in order to optimize the use of the warehouses. Only one constraint of IRPC is warehouse I4 which is the main warehouse in IRPC. IRPC is evaluating every warehouse whether it should be closed or not except warehouse I4. If warehouse I4 is

closed, warehouse operation in IRPC will face with a lot of trouble because I4 is the main loading place. IRPC is now considering modifying warehouse I4 to have more loading places. However, modifying warehouse is not included in this thesis. Therefore, warehouse I4 has to be opened according to the company constraint.

4.1.2 PTTCH Warehouse

There is no policy or constraint of PTTCH that their warehouses cannot be closed.

4.1.3 PTTPL Warehouse

PTTPL or PTT Polymer Logistics is the established company especially for servicing PTT group in logistics field for PTT and its subsidiaries. The warehouse of PTTPL is built as an international distribution center which uses modern technology to operate. PTTPL warehouse has been opened for only one year which means it was a newly built warehouse with large capacity, fully equipped, and high technology. PTTPL has only one warehouse and it cannot be closed due to the direction of the company to provide full logistics service for PTT Petrochemical subsidiary companies. Warehouse is then needed to be fulfilled in the logistics service.

4.1.4 HMC Warehouse

For warehouse H1, it was built concurrently with plant 3 to support the demand of products from plant 3. However, warehouse H1 just started to operate at the end of year 2010 so the constraint has begun. The information providing for analyzing in this thesis is not ready so there will be no evidence to tell the management that this warehouse should be closed. Furthermore, warehouse H1 is a newly established warehouse which can be believed that the new warehouse should be better than the old one. It is assumed that the lower age of the building, the better the condition of the building is (Sawicki and Zak)

In conclusion, there will be 4 warehouses that have to keep opened due to the policy and constraint of the company which are P1, H1, and I4.

4.2 Performance and Cost Step

Evaluating performance and cost are widely published in the literatures as well as the methodology to evaluate. Many of the literatures used AHP or analytic hierarchy process as the methodology to evaluate the performance and cost in warehouse. The goal of AHP is to select the alternative that results in the greatest value of the objective function (Linkov et al., 2009) which is the same direction of the goal in this thesis to seek the best alternative that gives the best benefits to PTT.

AHP or analytic hierarchy process is chosen to evaluate performance and cost using scoring method. There are three main steps in AHP which modified from Korpela, Lehmusvaara, and Nisonen (2007):

1) The criteria used for analyzing the warehouse performances are required
2) The criteria are structured into AHP-hierarchy
3) Properties are derived for the criteria and the corresponding requirements

This thesis will use these three steps as the framework to evaluate the performance and cost in PTT group companies.

4.2.1 Warehouse Performance Criteria

4.2.1.1 Common warehouse performance criteria

Bowersox and Closs (1996) stress the need to create process-oriented measurement which can be divided into measurements of internal and external performance.

Krakovics et al. (2008) proposed the indicators for internal performance of warehouse which include operational efficiency, inventory accuracy, and internal operation product damage. They also proposed the financial indicators which are distribution costs and moving and storage costs.

Rey (1999) suggests four groups of indicators: cost, productivity, quality, and time. Both indicators have the same direction in measuring warehouse performance.

Within warehousing and distribution, benchmarking has traditionally been focused on comparing quantitative performance measures, such as: operating cost, operating productivity, and response time and shipping accuracy. (Hackman et al., 2001).

The table below shows the warehouse performance criteria from various literatures comparing against each other.

Table 4.1: Warehouse Performance Criteria from Various Literatures

	Krakovics et.al. (2008)	Rey (1999)	Hackman et al. (2001)
Internal	Operational efficiency Inventory accuracy Internal operation product damage Distribution cost Moving and storage costs	Productivity Quality Cost Time	Operating productivity Operating cost
External			Response time and shipping accuracy

4.2.1.2 Selected warehouse performance criteria

The warehouse performance measurement in this thesis will cope with the internal performance only. Due to the fact that the external performance mostly involves with the transportation which is considered not included in the scope of this thesis. Transportation factors are normally evaluated the selection of truck and the selection of routing. Only one transportation factor considered in this thesis is transportation cost of the transferred product. Since there will be closed warehouse occurred, all of the products in those warehouses have to be transferred. If the

transportation cost of transferred product is not existed, the scenario in this thesis might not realistic. Due to the fact that the warehouses in PTT group companies are not situated in the same area, the transportation cost will not equal. The result of comparing the operational performance among PTT group warehouses will give the direction in deciding which warehouse should be closed.

The set of indicators proposed by Krakovics et al. (2008): operational efficiency, inventory accuracy, internal operation product damage, and moving and storage costs was chosen as the basis for this thesis. The reason that this thesis chose this set of indicators is that their case study is in the same industry as PTT group which is thermoplastic resin industry. Same industry usually has the same critical performance factors. Also, other literatures proposed the set of indicators in the same way as the chosen set of indicators. The chosen set of indicators covers all area of evaluating performance of the warehouse. Nevertheless, these indicators have to be measured in the case study companies so some of the indicator that considered being a hard-measure indicator is neglect. For example, the time used in each step in the warehouse operation is not measured. This is because there is no information gathered by the companies. At first, this thesis will evaluate this indicator by collecting the data myself. However, the officer said that you will not receive the true data due to the fact that they will do it more quickly than normal and it useless.

4.2.2 AHP-Hierarchy

4.2.2.1 Measurement

All companies need to measure and control their cost expenditure. But cost measurement is only one side of the coin of measurement. There is also the need to measure the utilization productivity and performance. It should be appreciated here, that the financial measures are always post-event, whereas productivity measures are virtually pre-event in examining the way resources are used on a daily basis (Emmett, 2005).

The set of performance indicators has to have a measurement. Sink and Tuttle (1989) claim that you cannot manage what you cannot measure. Jacek and Piotr proposed a set of 11 criteria that can be used to evaluate the usefulness of each warehouse in distribution system which are the optimality utilization of warehouses, forklift utilization index, material flow per warehouse worker, warehouse turnover per sq.m, holding cost per sq.m, modernity of warehouse, structure of warehouse building, internal climate on July, internal climate on January, working conditions in warehouse, and customer satisfaction.

This thesis proposed the set of performance indicators and how to measure these indicators illustrated in table 4.2.

Table 4.2: Criteria and Measurement

Criteria	Measurement
Operational efficiency	Product flow per warehouse worker Product flow per forklift
Inventory accuracy	Wrong product shipped of the warehouse (times)
Internal operation product damage	Product damage in warehouse (%)
Moving and storage costs	Warehouse operation cost per ton

There are four companies involved in this thesis. Therefore, the measurement has to be standard in order to gain the performance that can be compared in the same circumstance. These indicators are developed based on the literature and also the possible information given by PTT. All measurements proposed in this thesis can be gained from the four companies. If some measurement cannot gain from one of the four companies, that measurement cannot be used. Therefore, some measurement might also have an influence to the performance of the warehouse, but it does not exist due to the limited information. The equations of each measurement are illustrated below.

Table 4.3: Equations for Each Measurement

Measurement	Equation
Product flow per warehouse worker	$\frac{\text{The amount of products flow into warehouse in one year}}{\text{Number of warehousing worker}}$
Product flow per forklift	$\frac{\text{The amount of products flow into warehouse in one year}}{\text{Number of forklift}}$
Wrong product shipped of the warehouse (times)	Number of claims in one year
Product damage in warehouse (%)	$\frac{\text{Number of products damage}}{\text{The amount of products flow into warehouse in one year}}$
Warehouse operation cost per ton	$\frac{\text{Cost of warehousing in one year perspective}}{\text{The amount of products flow into warehouse in one year}}$

Zak and Sawicki expressed two involved measurements which are product flow per warehouse worker and holding cost. They said that the value of product flow per warehouse worker indicates the efficiency of human resource management and the productivity calculated by monetary value of material flow in a one-year perspective and number of warehousing workers. The efficiency of warehouse worker is calculated in the same way as the efficiency of other resources. Thus, the efficiency of forklift which is in one of the operational efficiency is calculated by monetary value of material flow in a one-year perspective and number of warehousing workers. Holding cost is a cost of warehousing in one-year perspective with reference to the amount of products flow into warehouse instead of warehouse area proposed in the work of Zak and Sawicki. The accuracy in quality is indicated by number of claims/ damages according to Amstel and D'hert (1996).

The ABC had been used to analyze the costs of warehousing activities in the work of Carles (2001). The activities performed in the warehouse have to be defined and then the costs that relevant to the activities defined are then identified.

Activity based costing is used to declared the costs occurred in the operations. There are three main costs occurred in the warehouse which are transferring from bagging to warehouse cost, storage cost, transferring from warehouse to truck cost, and loading to truck cost.

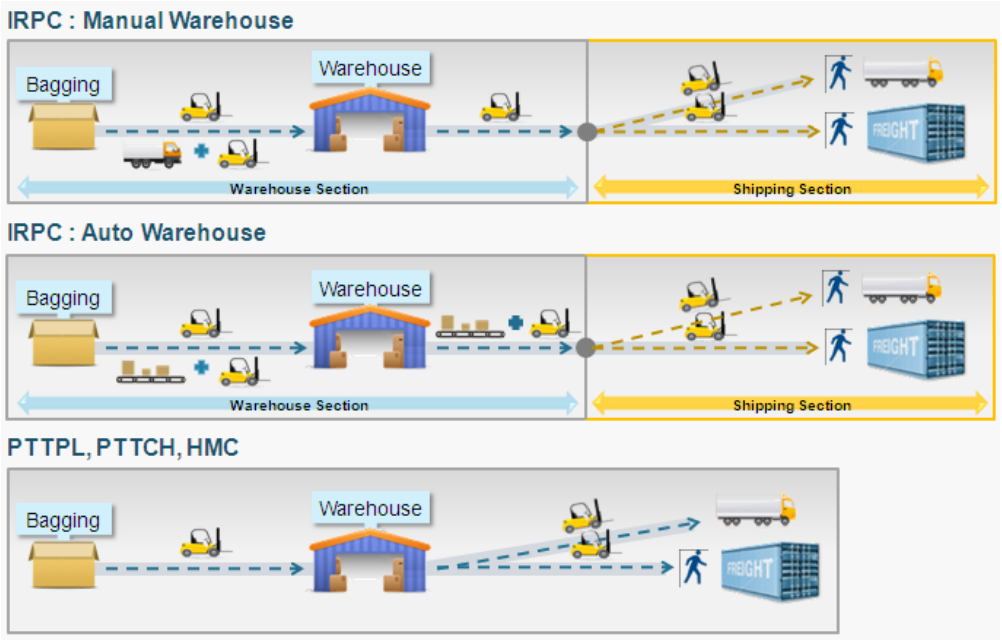


Figure 4.1: Warehouse Process

The transfer costs consist of the cost of forklift driver, truck driver, reach truck driver, checker, fuel consumption, and forklift rental. The storage costs are the maintenance cost, the electricity cost, and the officer cost. The loading cost is the cost of loading labor.

4.2.2.2 Hierarchy

The hierarchy of warehouse performance in PTT group is developed as illustrated below.

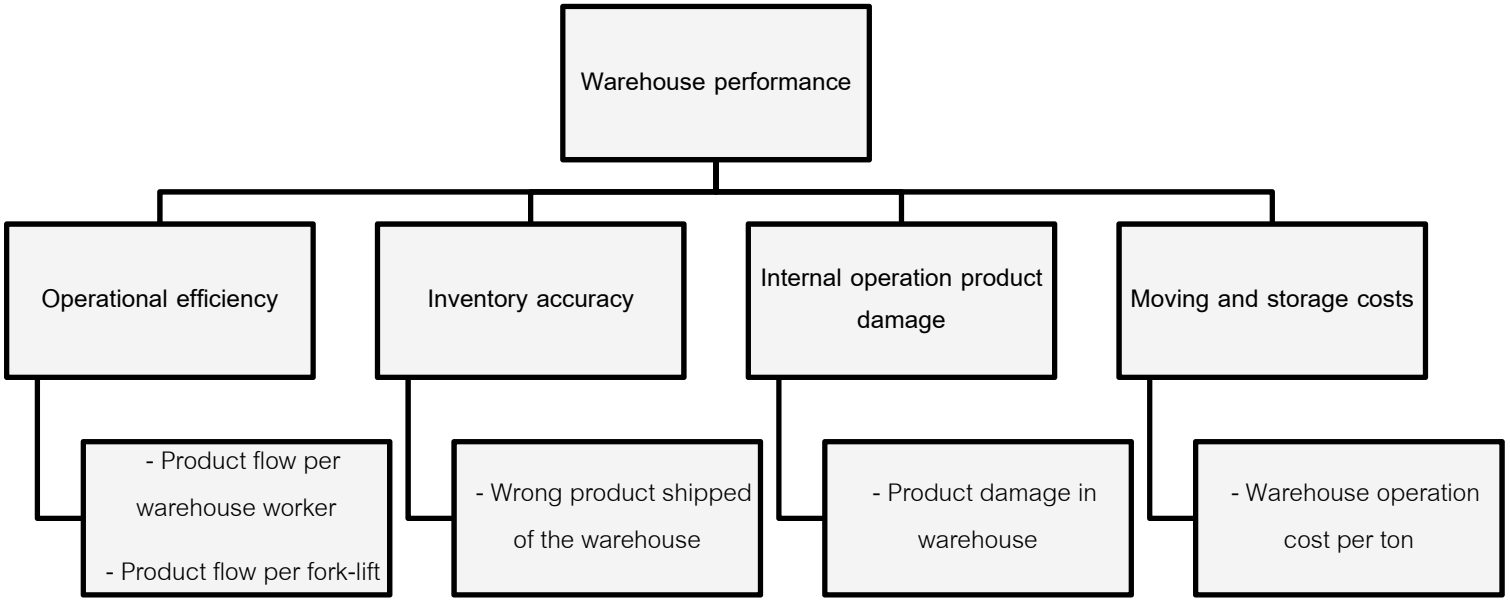


Figure 4.2: Hierarchy of PTT Warehouse Performance Evaluation

4.2.2.3 Case study company data

After setting the criteria and the measurement, the information given by PTT are applied in this thesis. The table below is the information of measurements in 2010 evaluated by each company.

Table 4.4: Measurements from the Case Study Companies

Warehouse	Warehouse Operation cost (Baht/ton)	Product damage (%)	Wrong product shipped of the warehouse (Times)	Product flow per worker (Pieces/worker)	Product flow per forklift (Pieces/forklift)
I1	122.14	2.000%	6	2,023.38	11,735.60
I2	110.10	4.000%	6	3,127.83	16,030.13
I3	215.44	22.900%	6	1,507.40	7,537.00
I5	116.48	0.004%	1	3,817.52	26,177.29
I6	117.24	0.003%	1	3,479.71	26,445.80
C1	36.07	0.010%	0	7,365.45	27,988.70
C2	34.71	0.010%	2	7,574.25	27,267.30
C3	53.43	0.010%	0	1,879.29	11,275.75

4.2.2.4 Relative priority

From the raw information given above, the priority of each warehouse is then evaluated with respect to each measurement. This priority will enable us to see the rough picture of the performance of the warehouse when comparing the other warehouses. The priority score will be gained with respect to each criterion after the calculation followed.

PRIORITIES OF ALTERNATIVES WITH RESPECT TO CRITERIA

	W1	W2	W3	W4	Priorities
(*C1*)					
W1	1	1/2	1/2	1/3	0.122
W2	2	1	1	1/2	0.227
W3	2	1	1	1/2	0.227
W4	3	2	2	1	0.424
				Total	1.000

Figure 4.3: Priorities of Alternatives with Respect to Criteria (Ho, 2007)

The example of priorities of warehouses with respect to criteria is illustrated below. This example is the warehouse operation cost example.

The priority of 3.39 is the relative priority when I1 is compared with C1

Table 4.5: The Example of Priorities

	Warehouse operation cost	122.14	110.10	215.44	76.36	116.48	117.24	36.07	34.71	53.43		
Warehouse operation cost	Warehouse	I1	I2	I3	I4	I5	I6	C1	C2	C3	Score	Adjusted score
122.14	I1	1.00	1.11	0.57	1.60	1.05	1.04	3.39	3.52	2.29	15.56	0.1385
110.10	I2	0.90	1.00	0.51	1.44	0.95	0.94	3.05	3.17	2.06	14.02	0.1248
215.44	I3	1.76	1.96	1.00	2.82	1.85	1.84	5.97	6.21	4.03	27.44	0.2443
76.36	I4	0.63	0.69	0.35	1.00	0.66	0.65	2.12	2.20	1.43	9.73	0.0866
116.48	I5	0.95	1.06	0.54	1.53	1.00	0.99	3.23	3.36	2.18	14.84	0.1321
117.24	I6	0.96	1.06	0.54	1.54	1.01	1.00	3.25	3.38	2.19	14.93	0.1329
36.07	C1	0.30	0.33	0.17	0.47	0.31	0.31	1.00	1.04	0.68	4.59	0.0409
34.71	C2	0.28	0.32	0.16	0.45	0.30	0.30	0.96	1.00	0.65	4.42	0.0394
53.43	C3	0.44	0.49	0.25	0.70	0.46	0.46	1.48	1.54	1.00	6.81	0.0606
											112.34	

The relative priority score of one warehouse with respect to another warehouse is done as in table above. The summary of priorities with respect to every measurement is shown in the table below.

Table 4.6: The Summary of Priorities

Warehouse	Warehouse Operation cost	Product damage	Wrong product shipped of the warehouse	Product flow per worker	Product flow per forklift
I1	0.1385	0.0646	0.2000	0.1884	0.1527
I2	0.1248	0.1293	0.2000	0.1219	0.1118
I3	0.2443	0.7402	0.2000	0.2528	0.2377
I5	0.1321	0.0001	0.0333	0.0998	0.0684
I6	0.1329	0.0001	0.0333	0.1095	0.0677
C1	0.0409	0.0003	0.0333	0.0517	0.0640
C2	0.0394	0.0003	0.0667	0.0503	0.0657
C3	0.0606	0.0003	0.0333	0.0503	0.1589

According to the information given above, there are two measurements which are in the same criteria in operational efficiency. These two measurements have to be summed into one number so the weighting is required.

Productivity of man and machine are important factor in warehouse process. The general warehouse process in PTT consists of receiving products from bagging, storing into warehouse, bringing products to the loading area, and loading into the truck. These activities are done by both man and machine. If there is no man, machine cannot receive the products to the warehouse. Therefore, the priority of product flow per worker and product flow per forklift are assumed to be equaled which means that the operational efficiency will gain from an average priority of the product flow per worker and product flow per forklift.

4.2.3 Prioritization

4.2.3.1 Weighting

Normally, the priority of the criteria is given by the decision makers by comparing between two criteria called pairwise comparison in AHP. However, this pairwise comparison has major disadvantages as described by Tahriri et al. (2007). They stated that if more than one person is working on this method, different opinions about the weight of each criterion can complicate matters. AHP also requires data based on experience, knowledge and judgment which are subjective for each decision-maker.

There is also another way to get the priority of the criteria by using the weighting of the reliable source. The work of Krakovics et.al. (2008) is considered to be one of the reliable sources. They studied the organization that is in petrochemical industry which responsible for 24% of the Brazilian production in PE and also playing an important role in other South American countries. Their case study company is considered to be an international company. Therefore, it can be used to benchmark with PTT who wants to increase its competitive advantage when compared to the other international companies. Furthermore, it is believed that the weighting is sensitive to the type of business according to Chan (2003). He also stated that the weighting of each performance measurement can be different for each industry. However, Krakovics et.al. (2008) and this thesis are in the same industry so the weighting of performance measurement should be used in the same circumstance. In addition, limitation is also from the case study company that the information in this weighting area cannot be provided. The weightings for PTT are shown below.

Table 4.7: The Weighting

Performance measurement	Weighting	Adjusted weighting
Operational efficiency	30%	20.0%
Inventory accuracy	30%	20.0%
Internal operation product damage	40%	26.7%
Moving and storage cost	50%	33.3%
Total	150%	100%

4.2.3.2 Overall score

The priorities with respect to the criterion are then sum with respect to the weighting. Therefore, the result of an overall score is established.

Table 4.8: The Overall Score for Each Warehouse

Weight	33.3%	26.7%	20%	20%	Overall score
Warehouse	Moving and storage cost	Internal operation product damage	Inventory accuracy	Operational efficiency	
I1	0.0462	0.0172	0.0400	0.0275	0.1309
I2	0.0416	0.0345	0.0400	0.0343	0.1504
I3	0.0814	0.1974	0.0400	0.0293	0.3481
I5	0.0289	0.0172	0.0400	0.0134	0.0995
I6	0.0440	0.0000	0.0067	0.0154	0.0662
C1	0.0443	0.0000	0.0067	0.0159	0.0669
C2	0.0136	0.0001	0.0067	0.0111	0.0314
C3	0.0131	0.0001	0.0133	0.0203	0.0468

After getting the overall score of every warehouse, the rank of warehouse in PTT Group company can be established as illustrated in table below.

Table 4.9: Warehouse Rank

Warehouse	Overall score
C1	0.0314
C2	0.0468
C3	0.0598
I5	0.0662
I6	0.0669
I1	0.1309
I2	0.1504
I3	0.3481

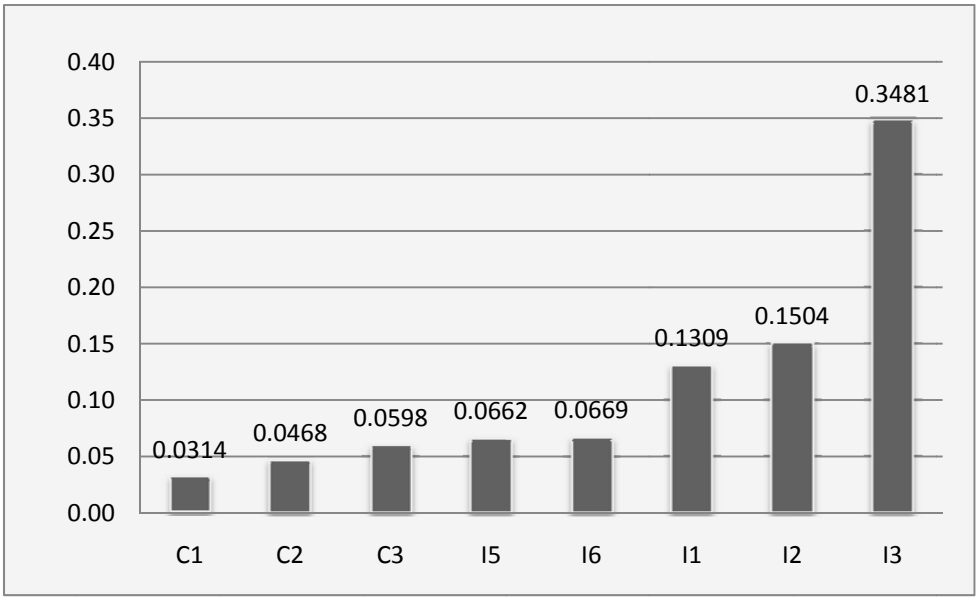
The fewer score, the better the warehouse is. On the other hand, the higher score, the worse warehouse is. Hence, warehouse C1 is the best among others while warehouse I3 is the worst among others.

4.2.3.3 Cut off point

According to the objective of the screening process to have the high performance warehouse with the optimum capacity, some bad warehouse should be closed. This step in performance and cost screening provides the preference of each warehouse. However, there must be some criteria to judge how many warehouses should be closed.

The figure below shows the overall score of each warehouse from the best to the worst. The performance of warehouse I3 is far worse than other warehouses that warehouse I3 has a relative change of the score 131% from warehouse I2. However, another warehouse clearly seen having the score quite far from the previous warehouse is warehouse I1. The evidence is shown that warehouse I1 has the relative change of the score equals to 96% when compared to warehouse I6. Therefore, the cutoff point cutting the bad warehouses is at warehouse I1.

Table 4.10: Relative Score of Each Warehouse



The last 3 warehouses are decided to be closed due to the fact that they have overall low performance and cost score. However, the objective of this process is to have the high performance warehouses with the optimum capacity. The capacity after closing the warehouse has to bear with the future demand in 2015. The needed capacity in 2015 is 142,817 tons at least. Therefore, the capacity after closing these three warehouses has to be more than 142,817 tons.

The capacity of closed warehouses equals to 68,784 tons so the capacity left is 251,744 tons which is more than the capacity needed in 2015 calculated before.

There are 5 warehouses that can be opened or closed after passing the performance and cost step in the screening process. These warehouses are I5, I6, C1, C2, and C3 which will be developed in the alternative further.

4.2.4 Sensitivity Analysis: Weighting against Warehouse Rank

In any MCDS situation here is uncertainty not only in the values of the criterion variables but also, for example, the weights of the criteria. In practical applications, a sensitivity analysis with respect to the uncertainty parameters used in the calculations is thus essential (Pukkala, 2002)

In this thesis, there is one set of parameter acquired from the literature which is the weighting for evaluating the overall score of each warehouse. According to Pukkala (2002) stated above, a sensitivity analysis is essential.

The weighting used in this thesis is shown in table 6.1. Also, the result of using these weightings is shown in table 6.2.

Table 4.11: The Performance and Cost Weighting in Sensitivity Analysis

Performance measurement	Present Weighting	Sensitivity analysis			
		-20%	+20%	+50%	+100%
Operational efficiency	30%	10%	50%	80%	130%
Inventory accuracy	30%	10%	50%	80%	130%
Internal operation product damage	40%	20%	60%	90%	140%
Moving and storage cost	50%	30%	70%	100%	150%

The use of the present weighting has put the warehouse rank from best to worst as C1, C2, C3, I5, I6, I1, I2, and I3 respectively and also has the cut off point which cut I2, I2, and I3 off to be closed.

This part will show the rank of warehouses after varying each criterion in order to see the effect of the criteria against the rank of the warehouse or the overall score of the warehouse. The table below shows the rank of the warehouses in each scenario.

4.2.4.1 Operational efficiency

Decreasing in operational efficiency has no effect to the rank of the warehouse. On the contrary, increasing in operational efficiency 20%, 50%, and 100% all affects the rank of the warehouse. The cut off point in every case is the same except in the case of increasing operational efficiency 100% that C3 also included to be closed.

4.2.4.2 Inventory accuracy

There is no effect on warehouse ranking when changing the inventory accuracy except the change of increasing 100%. The cut off point is still be the same.

4.2.4.3 Internal operation product damage

Internal operation product damage has no effect to the rank of the warehouse and the cut off point at all. All change both in an increasing and decreasing way cannot change the rank of the warehouse.

4.2.4.4 Moving and storage cost

Increasing the priority of moving and storage costs has no effect to the rank of the warehouse while decreasing the priority of moving and storage costs has an effect to the rank of the warehouse. For the cut off point, every case still has the cut off point that has to close I1, I2, and I3.

Table 4.12: Warehouse Rank after Changing the Weight

	-20%		+20%		+50%		+100%	
Operation efficiency	C1	0.0278	C1	0.0343	C1	0.0374	C1	0.0410
	C2	0.0384	C2	0.0532	C2	0.0604	C2	0.0686
	C3	0.0437	I5	0.0675	I5	0.0689	I5	0.0706
	I5	0.0645	I6	0.0684	I6	0.0701	I6	0.0720
	I6	0.0650	C3	0.0721	C3	0.0859	C3	0.1016
	I1	0.1299	I1	0.1317	I1	0.1326	I1	0.1336
	I2	0.1472	I2	0.1529	I2	0.1558	I2	0.1589
	I3	0.3791	I3	0.3243	I3	0.2976	I3	0.2673
Inventory accuracy	C1	0.0312	C1	0.0317	C1	0.0319	C1	0.0322
	C2	0.0437	C2	0.0491	C2	0.0518	C3	0.0492
	C3	0.0639	C3	0.0567	C3	0.0532	I5	0.0530
	I5	0.0712	I5	0.0623	I5	0.0580	I6	0.0535
	I6	0.0721	I6	0.0630	I6	0.0585	C2	0.0547
	I1	0.1203	I1	0.1390	I1	0.1482	I1	0.1586
	I2	0.1428	I2	0.1563	I2	0.1628	I2	0.1703
	I3	0.3708	I3	0.3306	I3	0.3110	I3	0.2888
Internal operation product damage	C1	0.0362	C1	0.0278	C1	0.0237	C1	0.0190
	C2	0.0539	C2	0.0413	C2	0.0352	C2	0.0282
	C3	0.0690	C3	0.0528	C3	0.0449	C3	0.0360
	I5	0.0763	I5	0.0584	I5	0.0497	I5	0.0397
	I6	0.0772	I6	0.0590	I6	0.0502	I6	0.0402
	I1	0.1411	I1	0.1231	I1	0.1144	I1	0.1044
	I2	0.1537	I2	0.1479	I2	0.1451	I2	0.1420
	I3	0.2877	I3	0.3942	I3	0.4461	I3	0.5049
Moving and storage costs	C1	0.0300	C1	0.0326	C1	0.0338	C1	0.0352
	C2	0.0479	C2	0.0459	C2	0.0449	C2	0.0438
	I5	0.0560	C3	0.0599	C3	0.0600	C3	0.0601
	I6	0.0568	I5	0.0739	I5	0.0826	I5	0.0925
	C3	0.0597	I6	0.0747	I6	0.0834	I6	0.0933
	I1	0.1298	I1	0.1318	I1	0.1328	I1	0.1339
	I2	0.1544	I2	0.1474	I2	0.1440	I2	0.1402
	I3	0.3640	I3	0.3359	I3	0.3221	I3	0.3065

In summary, there are 5 cases of changing the priority of the criteria that change the rank of the warehouse which are increase operational efficiency 20%, increase operational efficiency 50%, increase operational efficiency 100%, increase inventory accuracy 100%, and decrease moving and storage costs 20%.

4.3 Develop Alternatives Step

The framework of formulating alternatives will base on the work of Emanuel, Achille, and Hokey (2005). They developed the optimal network configurations for various values of access time as in Figure 4.4.

	Warehouse locations		τ (h)															
			7			8			9		10			11			12		
1	Terre Haute	IN	R			✓			✓	8	R			R			✓	8	
2	Greenville	TN	✓			✓			✓		✓			✓			✓		
3	Memphis	TN	X			✓			X		X			X			X		
4	Richmond	VA	R			X			X		X			X			X		
5	Paterson	NJ	X			X			X		X			X			✓	18	
6	Orlando	FL	X			X			X		X			X			X		
7	Bensenville	IL	✓	1	17	✓	17	19	✓	17	✓	17	19	✓	17	19	✓	17	19
8	Indianapolis	IN	✓			X			R		✓	1		✓	1		R		
9	Little Rock	AR	✓			✓			✓		✓			✓			✓		
10	Minneapolis	MN	✓			X			X		X			X			X		
11	Winnipeg	MB	✓			✓			✓		✓			✓			✓		
12	Montreal	QC	X			X			X		X			X			X		
13	San Leandro	CA	✓			✓			✓		✓			✓			✓		
14	Toronto	ON	✓			✓			✓		X			X			X		
15	York	PA	✓	4	18	✓	18		✓	18	✓	18		✓	18		X		
16	Dallas	TX	X			X			X		X			X			X		
17	Platteville	WI	R			R			R		R			R			R		
18	New Castle	DE	R			R			R		R			R			R		
19	Fond du Lac	WI	X			R			X		R			R			R		
20	Laredo	TX	✓			✓			✓		✓			✓			✓		
21	Atlanta	GA	✓			✓			✓		✓			✓			✓		

X, Warehouse closes; ✓, warehouse remains open; R, warehouse is relocated; #, warehouse # is consolidated.

Figure 4.4: The Optimal Network Configurations for Various Values of Access Time (Emanuel, Achille, and Hokey, 2005)

In order to develop the alternative without missing any of alternatives, this thesis uses the probability theory to develop the alternative. There are 5 variable warehouses left after passing 2 steps in the screening process due to the fact that 4 warehouses have to be opened from the policy and constraint and 3 warehouses have to be closed from the performance and cost step. Therefore, the number of alternatives to be developed is 32 alternatives.

Table 4.13: Developing Alternatives

	Alternative																															
WH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
I1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
I2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
I3	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
I4																																
I5		x					x	x	x	x							x	x	x	x	x	x					x	x	x	x		x
I6			x				x				x	x	x				x	x	x				x	x	x		x	x	x		x	x
C1				x				x			x			x	x		x			x	x		x	x		x	x	x		x	x	x
C2					x				x			x		x		x		x		x		x	x		x	x	x		x	x	x	x
C3						x				x			x		x	x			x		x	x		x	x	x		x	x	x	x	x
P1																																
H1																																

Note: x = Close, Blank = Open

4.4 Capacity Step

Evaluating the capacity in each alternative is done by dividing the use of the capacity by the capacity in each alternative. The use of the capacity is the demand of storing products in the year 2015 which is the same number for every alternative. However, the capacity in each alternative will be different due to the fact that there is different scenario in each alternative resulting in different amount of capacity left.

Jacek Zak and Piotr Sawicki stated that the optimal utilization is assumed to be 85%. In this thesis, the optimal utilization rate of 85% is used to be the criteria determining whether the alternative will pass or not. Low utilization will not give the good benefit to PTT since it means that there is more capacity left and the costs are higher. On the contrary, full utilization might not give the best scenario to PTT due to the fact that every plan should have a contingency plan. The future is not certain even though we have done the good forecasting. If the utilization rate of excess capacity is more than 100%, it means that alternative has not enough space to handle the future demand which implied that it is neglect.

Table 4.14: Utilization of Each Alternative

Alternative	Utilization of excess capacity	Alternative	Utilization of excess capacity
A1	57%	A17	107%
A2	72%	A18	105%
A3	69%	A19	95%
A4	63%	A20	91%
A5	62%	A21	84%
A6	58%	A22	83%
A7	92%	A23	86%
A8	81%	A24	79%
A9	80%	A25	78%
A10	74%	A26	70%
A11	77%	A27	125%
A12	76%	A28	111%
A13	71%	A29	109%
A14	68%	A30	94%
A15	64%	A31	88%
A16	63%	A32	130%

The flow of the screening process after passing capacity is shown below. There are 5 alternatives left after the screening by capacity which are A7, A19, A20, A30, and A31. These alternatives will be analyzed in the next step further.

4.5 Analyze Step

In order to analyze the benefit or feasibility in each alternative, the transfer destination of the products from the closed warehouse has to be specified unless it could not be analyzed. The assumption of the transfer method is that no partial capacity is consolidated into another warehouse according to Melachrinoudis, Messac, and Min (2005). The transfer procedure is described as followed.

4.5.1 Transfer procedure

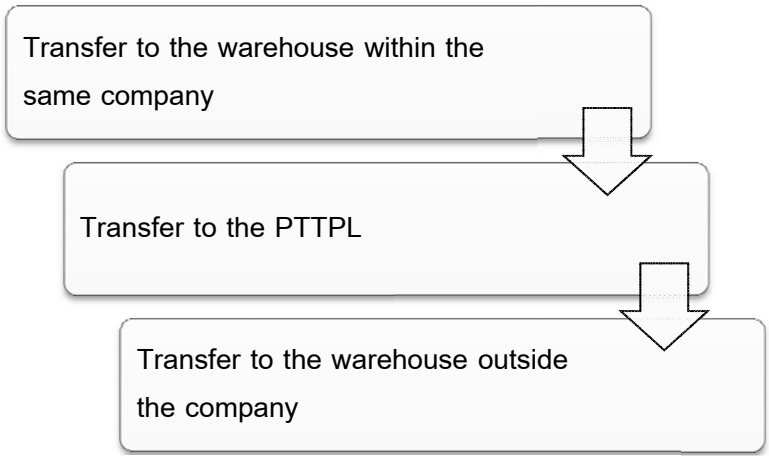


Figure 4.5: Transfer procedure

Seeing the real situation, it is impossible to transfer the product outside the company while there is still capacity left in the company. The transfer of products will occur only when the capacity in the company is not enough.

After the space within the company is all occupied, the next destination of transferring the products is PTTPL. Due to the fact that PTTPL is a company established especially on servicing logistics area for PTT Group companies, they have ability and also have a readiness to store the products of other companies. Furthermore, the warehouse of PTTPL is just built as an international distribution center which can be believed that their warehouse has the good operation system.

Lastly, the products will be transferred to the new warehouse according to the performance and cost score.

4.5.1.1 Example of transferring warehouse

The example of the transfer for alternative 7 is described below in Table 4.14. There are 5 warehouses that have to be closed which are I1, I2, I3, I5 and I6.

Table 4.15: Details of Alternative 7

Warehouse	Alternative 7	Demand (Tons)	Available capacity (Tons)
I1	x	10,250	
I2	x	13,462	
I3	x	1,081	
I4	√	7,681	9,109
I5	x	13,213	
I6	x	5,913	
C1	√	13,654	6,752
C2	√	8,288	10,032
C3	√	2,956	1,744
P1	√	41,594	38,406
H1	√	7,765	735
Utilization	92%		

1) Transfer within the company

There is only one IRPC warehouse open which has an available capacity of 9,109 tons. The possible selection to transfer is to transfer I3 and I6 due to the fact that the demand of storing products in 2015 from both warehouses is lower than 9,109 tons.

2) Transfer to PTTPL

After transferring I3 and I6 to I4, the products in I1, I2, and I5 have to be transferred also. According to the priority of the transfer destination, P1 is the most preferable one. P1 can still handle the amount of products of 38,406 tons. Thus, the products from I1, I2, and I5 will all be transferred to P1.

4.5.1.2 The summary of the transfer

Table 4.16: The Summary of the Transfer

Alternative	Closed warehouse	Transfer destination
A7	I3 and I6 I1, I2, and I5	I4 P1
A19	I3 and I6 I1, I2, and I5 C3	I4 P1 C1
A20	I2, I3 and I5 I1, C1 and C2	I6 P1
A23	I1, I2, I3 and I6 C1 and C2	I5 P1
A30	I2, I3 and I5 I1, C1, C2 and C3	I6 P1
A31	I1, I2, I3 and I6 C1, C2 and C3	I5 P1

4.5.2 Cost Benefit

The benefit in term of cost is the most attractive thing for every company as well as PTT. Cost is the first attraction to hand to the management in order to make them interest in this project.

The assumption to calculate cost in this thesis is to calculate cost based on the annual operation cost in 2010. Operation costs in this place consist of labor cost, fuel consumption cost, electricity cost, maintenance cost, and forklift rental cost. The operation cost of closed warehouses will be neglected. However, there will be the additional costs occurred after the transfer of products to the existing warehouses. These additional costs are transport cost, additional labor cost, additional forklift cost, and additional fuel consumption cost. Electricity and maintenance cost are considered to be the fixed cost for each warehouse.

4.5.2.1 Additional labor, forklift, and fuel consumption cost

The main idea to evaluate the additional labor or forklift is to look at the productivity of each warehouse. The assumption is that the productivity of man and machine in each warehouse will be constant in any circumstances. The number of additional man or machine will depend on the additional amount of products and the productivity of that warehouse.

The additional resource includes labor and forklift which can be calculated from the productivity of each warehouse.

$$\text{The additional resource} = \frac{\text{The additional amount of products}}{\text{The productivity of the warehouse}}$$

The summary of the additional labor and forklift of the transferred destination of the transferred products is illustrated in table .

Table 4.17: Additional Labor and Forklift

Alternative	Warehouse	Additional labor	Additional forklift
A7	I4	18	4
	P1	59	16
A19	I4	18	4
	P1	59	16
	C1	5	1
A20	I6	97	13
	P1	51	14
A23	I5	98	14
	P1	35	9
A30	I6	97	13
	P1	56	15
A31	I5	98	14
	P1	39	11

Table 4.18 shows the cost of extra labor and forklift that will occur after implementing this project. Each warehouse has different cost of hiring labor and renting forklift due to the information of 2010 given by each warehouse.

Table 4.18: Costs of Extra Resources

Warehouse	1 labor/year	1 forklift/year	Fuel consumption/1 forklift/year
I4	323,449	584,039	51,689
I5	374,823	349,500	34,751
I6	393,449	531,600	42,742.20
C1	213,082	264,000	50,000
P1	147,234	264,000	126,167

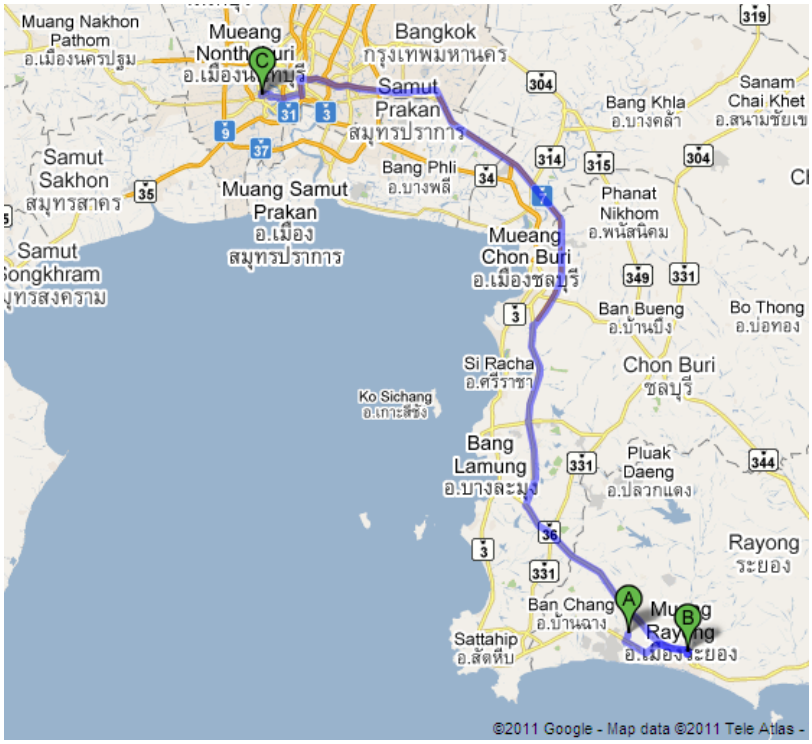
The summary of additional costs from labor, forklift, and fuel consumption is illustrated below.

Table 4.19: Additional Costs for Each Alternative

Additional cost (Baht/year)	Alternative					
	7	19	20	23	30	31
Labor cost	13,968,518	14,994,851	45,280,381	41,476,158	45,970,001	42,165,778
Forklift cost	6,180,109	6,514,736	10,554,575	7,376,581	10,889,203	7,711,209
Fuel consumption cost	2,174,456	2,237,833	2,297,023	1,673,427	2,456,942	1,833,347

4.5.2.2 Transport cost

Different location created different cost of transportation. There are two main transportations in this thesis to be considered. The first one is the transportation from the warehouse to the customer while the second one is the transportation from the warehouse to the new warehouse destination.



Note: A = Maptaphut, B = Cherngnern, and C = Bangkok

Figure 4.6: Map of Warehouses and the Main Destination

1) The transportation from the warehouse to the customer

There are two groups of warehouses which are warehouses in Maptaphut and warehouses in Cherngnern. Both groups of warehouses are in Rayong province, but drift apart each other approximately 20 km.

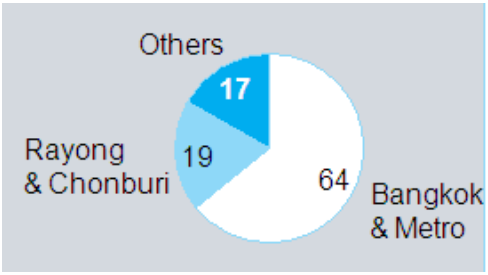


Figure 4.7: The Customer Areas

According to the figure above, the main destinations of the customer in PTT Group companies are Bangkok & metro and Rayong & Chonburi. The location of Maptaphut is near these two destinations more than Cherngnern. However, the costs of transportation of these two warehouses are almost the same so there is no calculation of benefit in this category.

2) The transportation from the warehouse to the new warehouse destination

Table 4.20: Transport Cost

From-to	Transport cost (Baht/ton)
IRPC to MTP	90
MTP to MTP	60

Even though there is no difference in cost of transportation from the warehouse to the customer, there is still the difference in the cost of transportation from the warehouse to the new warehouse destination. The reason that there is no difference of the cost from the warehouse to the customer might be the total distance from Rayong to Bangkok is about 200 km so the difference in 20 km is not significant. However, the cost of transportation in Maptaphut is 60 Baht per ton while the cost of transportation from Cherngnern to Maptaphut is 90 Baht per ton.

Therefore, there will be an extra cost in transportation when there is a transfer from the warehouse to the new warehouse destination both from Maptaphut to Maptaphut and Cherngnern to Maptaphut.

4.5.2.3 Cost summary

The summary of costs including operation cost and extra costs occurred in each alternative is illustrated in the table below.

Table 4.21: Cost Summary (Baht)

Alternative	7	19	20	23	30	31	Present
Operating cost (baseline)	78,931,182	76,725,892	86,745,666	86,459,673	83,069,539	82,783,546	238,428,548
Extra cost							
Man	13,968,518	14,994,851	45,280,381	41,476,158	45,970,001	42,165,778	-
Machine	6,180,109	6,514,736	10,554,575	7,376,581	10,889,203	7,711,209	-
Transport	39,879,095	39,879,095	26,868,338	15,798,230	28,996,928	17,926,820	-
Fuel	2,174,456	2,237,833	2,297,023	1,673,427	2,456,942	1,833,347	-
Total	141,133,360	140,352,407	171,745,983	152,784,069	171,382,614	152,420,700	238,428,548

From Table 4.20, every alternative gives the benefit in costs more than the current cost occurred at the present. However, the best alternative that gives the lower annual costs to the company is from alternative 19. This alternative can save the cost for PTT around 100 million Baht per year.

The summary of the screening process including the result is illustrated in the figure below

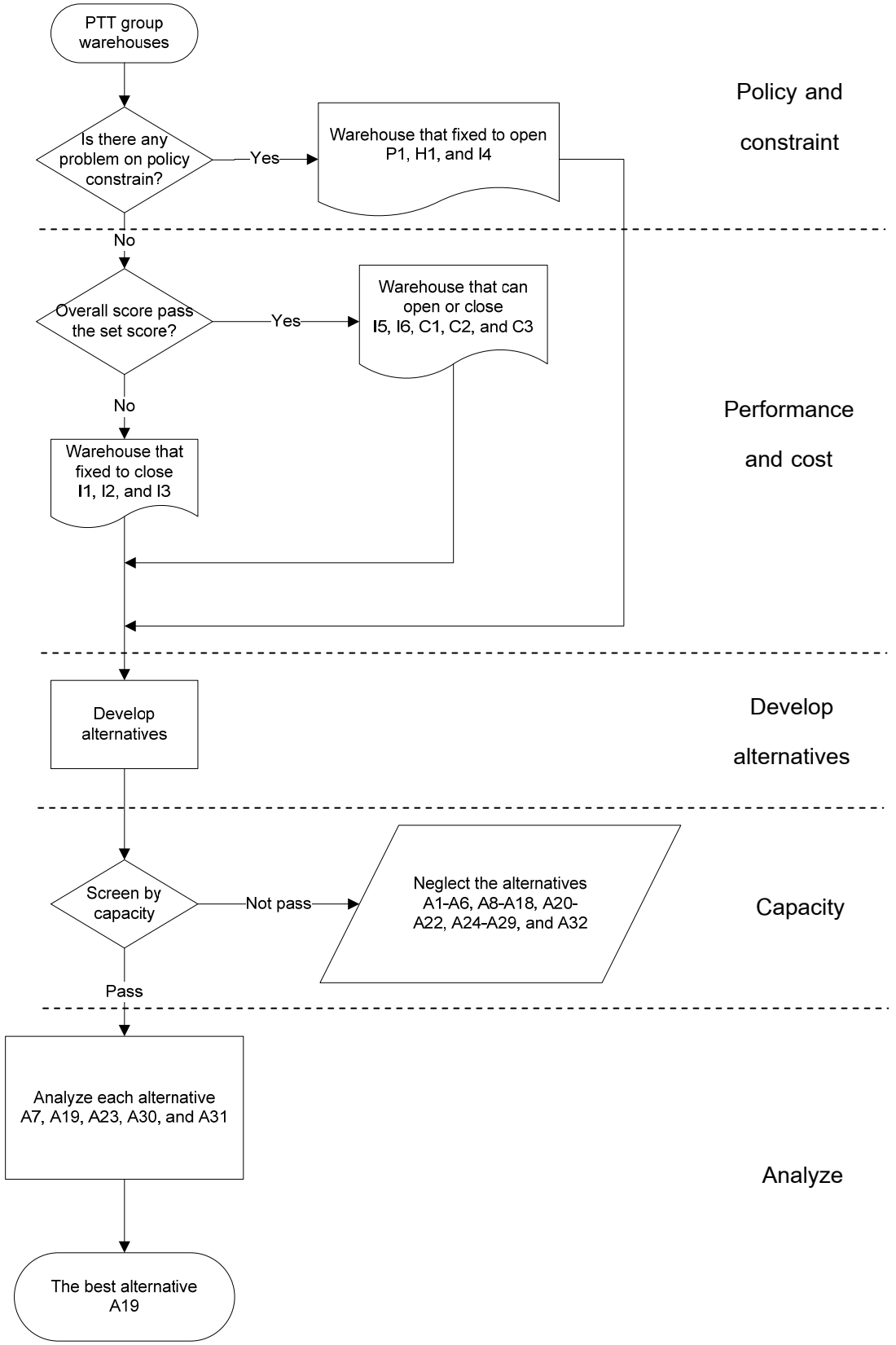


Figure 4.8: Summary of the Screening Process

4.5.3 Sensitivity Analysis: Weighting against the Selected Alternative

As described before, the weight of the set of performance criteria affects the rank of warehouse which might affect to the selected alternative. The best alternative might be changed if the weight of the performance criteria changed. Therefore, this thesis will vary these criteria one by one in order to acknowledge the effect of these criteria to the selected alternative. The result after the variation will show the effect of each criterion to the alternative given the best benefits to PTT.

If the cut off point is the same, the alternatives passed the capacity step to analyze step will be the same. Nevertheless, some cases have the different rank of warehouse so the transfer destination might be changed resulting in the new costs and the new selected alternative. However, if there is a change in cut off point, there is a chance to create the new developed set of alternatives. New set of alternatives will be screened by the capacity and analyze step further.

In summary, there is one condition that the selected alternative will certainly be the same which is the condition that the warehouse rank was not changed and the cut off point was the same. After finding the cut off point for every case, the cut off point is the same for all cases except one case which is the case that the operational efficiency increases up to 100%. Therefore, there will be 5 cases that have to be analyzed in details since they have not in the condition that the warehouse was not changed and the cut off point was the same which are increasing operational efficiency 20%, increasing operational efficiency 50%, increasing operational efficiency 100%, increasing inventory accuracy 100%, and decreasing moving and storage costs 20%.

4.5.3.1 Operational efficiency

The rank of the warehouse for increasing 20%, 50%, and 100% operational efficiency is the same as each other, but changed from the current rank. However, increasing 100% operational efficiency adds another warehouse to cut off which is warehouse C3. There will be 6 alternatives passing the capacity step as the same except for the case of increasing 100% that the alternatives passing the capacity

step will be just three which are A19, A30, and A31 due to the close of warehouse C3. The transfer destination is then developed in order to analyze the benefit occurred.

Table 4.22: Transfer Destination: Change in Operational Efficiency Weight

Alternative	Closed warehouse	Existing transfer destination	Transfer destination for 20% and 50%	Transfer destination for 100%
7	I3 and I6 I1, I2, and I5	I4 P1	I4 P1	-
19	I3 and I6 I1, I2, and I5 C3	I4 P1 C1	I4 P1 C1	I4 P1 C1
20	I2, I3 and I5 I1, C1 and C2	I6 P1	I6 P1	-
23	I1, I2, I3 and I6 C1 and C2	I5 P1	I5 P1	-
30	I2, I3 and I5 I1, C1, C2 and C3	I6 P1	I6 P1	I6 P1
31	I1, I2, I3 and I6 C1, C2 and C3	I5 P1	I5 P1	I5 P1

As seen from the table below, the transfer destination is not changed so the alternative selected will not be changed due to the fact that the costs evaluated in each alternative are the same. In conclusion, alternative 19 is still considered to be the best alternative even the operational efficiency changed.

4.5.3.2 Inventory accuracy

The rank of warehouse changed from the current rank of warehouse when there is an increasing of 100% inventory accuracy weight. The cut off point of an increasing of priority in inventory accuracy is the same as the existing cut off point which is to cut I1, I2, and I3 out.

Table 4.23: Transfer Destination: Change in Inventory Accuracy Weight

Alternative	Closed warehouse	Existing transfer destination	Transfer destination for 100%
7	I3 and I6 I1, I2, and I5	I4 P1	I4 P1
19	I3 and I6 I1, I2, and I5 C3	I4 P1 C1	I4 P1 C1
20	I2, I3 and I5 I1, C1 and C2	I6 P1	I6 P1
23	I1, I2, I3 and I6 C1 and C2	I5 P1	I5 P1
30	I2, I3 and I5 I1, C1, C2 and C3	I6 P1	I6 P1
31	I1, I2, I3 and I6 C1, C2 and C3	I5 P1	I5 P1

As seen from the table above, the transfer destination is not changed so the alternative selected will not be changed due to the fact that the costs evaluated in each alternative are the same. In conclusion, alternative 19 is still considered to be the best alternative even the operational efficiency changed.

4.5.5.3 Moving and storage costs

The rank of warehouse changed after the change in decreasing 20% moving and storage costs weight. The cut off point of a decreasing of priority in inventory accuracy is the same as the existing cut off point which is to cut I1, I2, and I3 out.

Table 4.24: Transfer Destination: Change in Moving and Storage Costs Weight

Alternative	Closed warehouse	Existing transfer destination	Transfer destination for 100%
7	I3 and I6 I1, I2, and I5	I4 P1	I4 P1
19	I3 and I6 I1, I2, and I5 C3	I4 P1 C1	I4 P1 C1
20	I2, I3 and I5 I1, C1 and C2	I6 P1	I6 P1
23	I1, I2, I3 and I6 C1 and C2	I5 P1	I5 P1
30	I2, I3 and I5 I1, C1, C2 and C3	I6 P1	I6 P1
31	I1, I2, I3 and I6 C1, C2 and C3	I5 P1	I5 P1

As seen from the table above, the transfer destination is not changed so the alternative selected will not be changed due to the fact that the costs evaluated in each alternative are the same. In conclusion, alternative 19 is still considered to be the best alternative even the operational efficiency changed.

The summary of the sensitivity analysis results is illustrated in Table 4.24. The final result is still be the alternative 19 due to the fact that the performance score from each company is quite far away from each other and the transfer destination is the same. Most of the transferred products are transferred to warehouse P1 which is not included in the calculation of the score so the changes in score will almost no effect to the transfer destination, except the transfer within the company. No change in transferring means no change in the benefits occurs.

Table 4.25: The Result of Changing of the Weight

	Operation efficiency	Inventory accuracy	Internal operation product damage	Moving and storage cost
-20%				
W/H	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>I5>I6>C3>I1>I2>I3
Cut off	I1,I2,I3	I1,I2,I3	I1,I2,I3	I1,I2,I3
Alternative	A19	A19	A19	A19
+20%				
W/H	C1>C2>I5>I6>C3>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3
Cut off	I1,I2,I3	I1,I2,I3	I1,I2,I3	I1,I2,I3
Alternative	A19	A19	A19	A19
+50%				
W/H	C1>C2>I5>I6>C3>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3
Cut off	I1,I2,I3	I1,I2,I3	I1,I2,I3	I1,I2,I3
Alternative	A19	A19	A19	A19
+100%				
W/H	C1>C2>I5>I6>C3>I1>I2>I3	C1>C3>I5>I6>C2>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3	C1>C2>C3>I5>I6>I1>I2>I3
Cut off	I1,I2,I3,C3	I1,I2,I3	I1,I2,I3	I1,I2,I3
Alternative	A19	A19	A19	A19

CHAPTER V

PROCESS EVALUATION

This thesis developed the screening process to evaluate the warehouse of PTT and also chose the alternative that gives the best benefits for them. Nevertheless, some assumptions and limits have been set before the selected alternative chosen. Therefore, this chapter will discuss the result in various aspects and also give the rough picture for implementing the selected alternative.

5.1 The Selected Alternative

The selected alternative that gives the best benefits to PTT is alternative 19. However, there is another alternative that gives the benefits to PTT near alternative 19 which is alternative 7.

Alternative 7 and alternative19 have almost the same warehouse operation cost, but A19 has better cost a little bit. They almost have the same option in opening and closing the warehouse except that A19 also close warehouse C3 while A7 is not.

Therefore, these two best alternatives have the same direction in opening and closing the warehouse in PTT Group so this can be the indication that this direction is the right way to be improved.

5.2 Feasibility of the selected alternative

Except the benefit in cost reduction as analyzed in previous section, the feasibility provided to PTT Group companies from the selected alternative will also illustrated.

There will be 6 warehouses closed from alternative 19 which are I1, I2, I3, I5, I6 and C3. Most of these warehouses all belong to IRPC except C3 which belongs to PTTCH.

5.2.1 Feasibility: IRPC

According to the logistics section in IRPC, They received an order from their top management to reconsidering their warehouse assets as they think they have too many warehouses. The previous owner of IRPC gave the direction to build the warehouse as he built the plant. Therefore, the numbers of warehouse in IRPC are 6 warehouses. The demand of using warehouses of IRPC and PTTCH is close to each other. However, PTTCH has only three warehouses. Thus, it sounds make sense if IRPC will reduce some of their warehouses. Furthermore, IRPC already has a plan to close some of their warehouses by their own before this project of PTT so the feasibility to close some of their warehouses is possible.

According to Melachrinoudis, Messac, Min (2005), it is also interesting to note that most of the retained warehouses, including the consolidated ones, are either at the center, or in the vicinity of the center of concentrated demand locations. Due to the fact that IRPC is situated in Cherngnern which far from Maptaphut around 20 km, transferring products might not flexible. Furthermore, cooperation with the company closing to each other will drive the synergy easier.

Warehouse I5 and I6 are automatic warehouses while other warehouses in PTT Group are the manual warehouse. Instead of using manpower, automatic warehouse use machine to operate activities in the warehouse; put away into the storage area and picking.

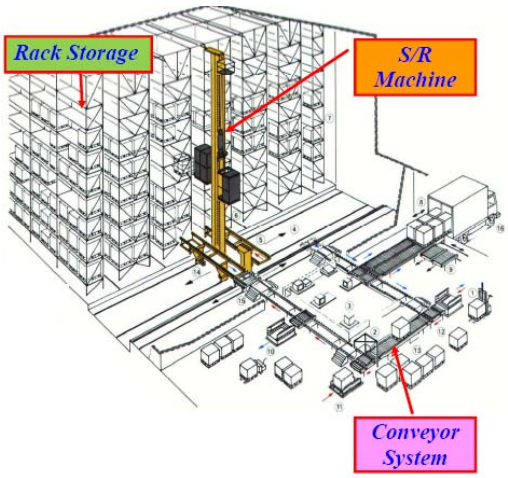


Figure 5.1: Automatic Warehouse

However, there are many disadvantages in an automatic warehouse which are relatively inflexible in terms of throughput, load size, operating patterns and future changing requirements, vulnerable to software failures, and requires greater care in standardized packaging and bar codes/product identifications according to Emmett (2005). The main advantage of using automatic warehouse is using fewer people which can reduce the labor costs. Nevertheless, the labor rate in Thailand is quite low compared to other countries so an automatic warehouse might not give a high benefit as in other countries. In addition, an automatic warehouse use in the dark operation and has narrow space which create an inconvenience in maintenance resulting in high maintenance costs. The frequent problem of automatic warehouse asked from the IRPC officer is that the loading size. Due to the fact that an automatic warehouse uses machine to operate, there is a sensor checking the products when pallet is in the line. However, the size of the loading is fixed and that pallet cannot be stored in the automatic warehouse. Therefore, using manual warehouse will not face with these problems.

There are two types of storage in the table which are rack and floor. Rack is useful for those warehouses which have limited space, but in the same time require high capacity.

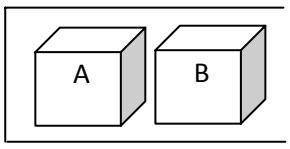


Figure 5.2: Rack Storage

The problem for using racking in warehouse I1 and I2 is that product B has to be removed and placed in some place in order to bring product A out for sale. After that, product B is put in the product A location. Hard handling of racking creates inconvenience which is one of the main reasons that I1 and I2 have low utilization. Since I1 and I2 create inconvenience, IRPC try to bring their products to other warehouses instead. Inconvenience movement, additional machine (reach truck), more handling, and also higher maintenance make most of the company choose floor storage.

5.2.2 Feasibility: PTTCH

Warehouse C3 is the smallest warehouse in PTTCH which has the proportion only 11% compared to the overall capacity of PTTCH warehouses. Reducing the capacity only 11% might not affect the operation in PTTCH. In addition, the future demand of the products in PTTCH is around 24,898 tons per month while the capacity of C1 and C2 is 38,726. Hence, there is still an unoccupied capacity in PTTCH more than 10,000 tons per month.

5.3 Inventory Turnover Ratio

Inventory turnover ratio has a big effect to his thesis since it determines the level of capacity used in the future. There is an assumption in this thesis that the inventory turnover ratio in 2015 is equaled to the inventory turnover ratio in 2010. This assumption has gained from the information of the case study company that they would like to keep the inventory turnover ratio at a constant rate. Furthermore, the trend towards the future direction of the company is to try to produce the product as the made-to-order, not made-to-stock. Therefore, the inventory turnover ratio should be higher, not lower which means that the warehouse will have more spaces than the evaluation did.

However, this thesis will provide the information in case that the inventory turnover ratio is dropped half compared to the present which means that the case study company may require more warehouse to be opened.

The inventory level and the excess capacity when the inventory turnover ratio dropped half is shown in the table below.

Table 5.1: Inventory Level in 2015: Change in Inventory Ratio

	Warehouse Capacity	Inbound 2010	Inbound 2015	Inventory turns	Inventory level 2015	Excess capacity
I1	34,309	117,356	123,223.80	6	20,500	13,809
I2	33,415	128,241	134,653.05	5	26,924	6,491
I3	1,060	7,537	7,913.85	3	3,073	(2,013)
I4	16,790	294,024	308,725.20	20	15,362	1,428
I5	50,208	183,241	192,403.05	7	26,426	23,782
I6	40,320	132,229	138,840.45	12	11,827	28,494
C1	20,406	279,887	375,048.58	14	27,308	(6,902)
C2	18,320	272,673	365,381.82	22	16,576	1,744
C3	4,700	45,103	60,438.02	10	5,913	(1,213)
P1	80,000	333,237	536,511.57	6	83,189	(3,189)
H1	8,500	58,108	85,418.76	6	15,531	(7,031)
EXT		29187	42904.89	2	21452	
Total	308,028				274,081	33,947

There is still an unoccupied capacity left when the inventory turnover ratio drop half which can be implied that the existing capacity is a lot more than necessary. The circumstance of the half drop of inventory turnover ratio is hard to be occurred in the real situation. However, this thesis will provide an image of seeking for the best alternative in this circumstance for some consideration.

There are 6 possible alternatives to be developed as shown in Table 5.2. The utilization rate of each alternative is also illustrated.

Table 5.2: Developed Alternatives: Change in Inventory Turnover Ratio

Warehouse	B1	B2	B3	B4	B5	B6
I1						
I2						
I3	x	x	x	x	x	x
I4						
I5						
I6						
C1		x			x	
C2			x			x
C3				x	x	x
P1						
H2						
Utilization rate	89%	96%	95%	91%	97%	97%

Note: x = Closed warehouse, Blank = Open warehouse

Then each alternative is analyzed in term of cost to show the benefit after the change. However, there is no alternative that gives better benefits compared to the present operating cost. Therefore, it can be concluded that if the inventory turnover ratio is dropped half of the present amount, the option of phasing out some of the PTT warehouses is not the best option for them.

Table 5.3: Cost Summary: Change in Inventory Turnover Ratio

Alternative	B1	B2	B3	B4	B5	B6	Present
Operating cost (baseline)	236,223,258	224,586,140	224,800,097	232,547,132	220,910,013	221,123,970	238,428,548
Extra cost							
Man	3,748,232	10,226,538	9,502,864	5,879,053	10,446,358	9,195,899	
Machine	699,000	3,867,000	2,811,000	849,000	4,659,000	3,339,000	
Transport	-	19,661,498	11,934,962	4,257,180	23,918,678	16,192,142	
Fuel	69,502	1,583,501	469,502	219,502	1,733,501	569,502	
Total	240,739,992	259,924,678	249,518,425	243,751,866	261,667,551	250,420,513	238,428,548

5.4 Capacity

According to the criteria used to screen the capacity, the utilization rate of 85% is used as in the literature review. However, there might be a doubt in neglecting the other alternatives that give the utilization rate near 85%. Therefore, this thesis will illustrate the benefit of the alternatives near 85% to look whether they give better benefits or not.

The alternatives that have the utilization rate between 76% and 85% will be analyzed additionally so there will be extra 8 alternatives to be analyzed which are A8, A9, A11, A12, A21, A22, A24, and A25. The operation costs of each alternative including the additional costs are shown in Table 5.4.

Table 5.4: Costs Summary: Additional Alternatives

Alternative	A8	A9	A11	A12	A21	A22	A24	A25	Present
Operating cost (baseline)	156,642,478	156,856,435	156,356,486	156,570,443	152,966,352	153,180,309	152,680,359	152,894,316	238,428,548
Extra cost									
Man	43,854,905	42,603,284	39,901,016	38,649,395	44,884,458	43,662,024	40,930,568	39,675,728	
Machine	9,510,886	8,903,555	6,538,133	5,930,803	9,854,366	9,238,183	6,881,614	6,265,431	
Transport	20,900,857	17,037,589	9,830,749	5,967,481	20,900,857	30,845,183	9,830,749	5,967,481	
Fuel	1,840,201	1,549,956	1,235,004	944,759	1,905,254	1,613,332	1,300,057	1,008,135	
Total	232,749,327	226,950,820	213,861,387	208,062,880	230,511,288	238,539,031	211,623,348	205,811,091	238,428,548

The operation costs of these extra alternatives are quite not interesting due to the fact that their costs close to the present operating costs. Conversely, the operation costs of alternative 19 of 140,352,407 Baht are more interesting since it can save the money around 100 million Baht.

5.5 Closed Down Warehouses

For the warehouses that have to be closed, there are three main things that have to be considered which are labors, machines, and the building.

5.5.1 Labor

Labors used to work in the warehouse that has to be closed have to be discharged. Five of six warehouses are owned by IRPC which means that the main labor that has to be discharged is an IRPC labor. According to the fact that IRPC has put too many resources to operate their warehouses, PTT and IRPC themselves already concerned at this point. The policy to reduce the number of IRPC employee has been done since PTT bought IRPC from the previous owner. Therefore, the problem of discharging IRPC labor might not give a bad effect as it should be. Furthermore, these amounts of discharged labors will have an opportunity to transfer to other units in the company or transfer to the warehouse that needs more labor to work on.

5.5.2 Machine

There are many machines in the warehouse. Some machines are bought while some are rented. The main machine used to operate in warehouse is forklift which every company rented from outside so there is no problem in this case. For the machine bought, some can be transferred to the other warehouses and some can be sold.

5.5.3 Building

Warehouse buildings might be demolished in order to gain the benefit in using the land that the warehouse existed. At present, the permission asking for the land to build the plant in Maptaphut area is hard to be received due to the pollution concern. However, the land especially the land of the IRPC warehouses is already allowed to build the plant. Therefore, the production plant that IRPC has been planning to expand can be done in the land of the closed warehouses.

5.6 Proposed operation

The proposed operation for implementing this alternative is to have each company operates for their own warehouses. This is because the relationship between the production and the warehouse operation. The production plan is considered to be some of the secret for every company. The thing is that the production unit has to coordinate and tell the plan to the warehouse unit in order to make them handle the products. If the production unit and the warehouse unit are not the same company, the problem will certainly occur due to the lack of trust in different company.

For IRPC and PTTCH who have to transfer the products to PTTPL, they have to pay PTTPL for the operation costs to store their products. Transferring products from IRPC and PTTCH, storing products, and shipping products are the duty of PTTPL in servicing warehouse operation. IRPC and PTTCH have to pay for all the operations PTTPL has done.

In the first phase of implementing, PTTPL should be the advisor for the other companies to go along with the plan until they can manage by themselves.

5.7 Validation

The validation of this thesis has been done by the logistics officer of the case study company who has the responsibility to look at the warehousing area in the logistics master plan project.

This study framework in domestic warehouse will contribute benefits to PTT and also brought to the real implementation. This is because this study aims to create value added and do with the existing assets without further investments. Also, fix cost in each company can be capitalized on.

In summary, from the assumption, the screening criteria, weighting, evaluating cost, to developing alternative is considered to be reasonable and considered to be one of the good methodologies which suitable and conform to the objective of the study to find

the way to improve and optimize the warehouse in PTT Group in order to gain the best benefits. The way to select the criteria, comprehensive weighting scale and given the importance in every area makes the consideration and analysis correct and perfect. Therefore, the best alternative selected in this thesis is the best alternative in my opinion and possible to implement in PTT Group.

CHAPTER VI

CONCLUSION

6.1 Conclusion

Since PTT has many sub-ordinates that operate in the same industry, increasing the efficiency and reduction of costs can be done by the coordination of those companies. However, these companies are currently operating individually without any coordination or collaboration especially in the solid petrochemical warehouses of PTT. There are 11 warehouses from four companies which are IRPC, PTTCH, PTTPL, and HMC. The primary problem from these warehouses is that there are a lot of spaces left unoccupied which means that these companies are wasting their costs for nothing.

The future demand in 2015 has been calculated in order to acknowledge whether the warehouses still having spaces unoccupied or not. The result is still the same which around 50% unoccupied so this thesis will provide the way to solve this problem as a 5 years plan.

After getting through the common improvement in warehousing area, the most suitable option for PTT is to phase out some of the existing warehouses. However, the methodology to judge which warehouse should be closed and how many to close is needed. The screening criteria are established in this thesis in order to choose the best alternative that gives the best benefits to PTT.

Four criteria are chosen to use in the screening process which acquired from the literature, but also consider the suitability with PTT. Policy and constraint, performance and cost, capacity, and location are used to develop the screening process.

There are 5 main steps in the screening criteria which are policy and constraint, performance and cost, develop alternatives, capacity, and analyze respectively.

Policy and constraint is the first step to screen due to the fact that the direction or the decision of the company is normally comes first. There are three warehouses that

have to keep open due to the policy or constraint of the company which are PTTPL warehouse (P1), one of IRPC warehouse (I4), and HMC warehouse (H1).

Performance and cost is the second step in the screening process. This step will help screen the low performance warehouse and high cost out. Analytical Hierarchy Process (AHP) has been used as the framework to evaluate the performance and cost of each warehouse. There are four criteria in evaluating the performance and cost in the warehouse which are operational efficiency, inventory accuracy, internal operation product damage, and moving and storage cost. The data from PTT will be prioritized relatively in each criterion and summed by the weight specified. The overall score of each warehouse will indicate the rank which then used to cut some warehouses off. In this step warehouse I1, I2, and I3 from IRPC are decided to close down.

The third step is the develop alternatives step. This step has to be done before screening by the capacity due to the fact that after the alternative developed, the details of which warehouse is closed or opened will be demonstrated which can be used to calculate the capacity. There are 32 alternatives developed since there are 5 warehouses that can be closed or opened while the other 6 warehouses are fixed.

After developing the alternatives, screening by the capacity is the next step to be done. Actually, the capacity can be done at the first place before screening b the performance and cost. However, there is no reason to do that because there will be many alternatives that pass the capacity criterion but contains the low performance and high cost warehouses which finally neglect. The utilization rate of 85% is used to screen the alternatives.

The last step is the analyze step which will consider about the benefits PTT will gain after implementing according to the selected alternative. However, the transfer of products in the closed warehouse has to be specified before analyzing the benefits due to the fact that there will be some costs occur after the transfer. The transfer procedure is to transfer to the warehouse within the same company first and then transfer to the best performance warehouse outside the company. The costs calculated in this thesis

consist of operating cost, additional cost from extra employee, additional cost from extra forklift, transportation cost, and additional fuel consumption cost.

After analyzing, the best alternative is selected which can reduce the cost around 100 million Baht per year. The alternative that gives the best benefits to PTT is alternative 19 which has to close 6 warehouses; I1, I2, I3, I5, I6, and C3. The feasibility of implementing this alternative also analyzed which shows that there is possibility to implement this selected alternative.

The sensitivity analysis is performed in this thesis. Since the weighting for summing the score of performance and cost criteria is acquired from the literature, sensitivity analysis will help demonstrate the effect of the change in the selected alternative to the change of the weighting. This thesis provides four main scenarios which are -20%, +20%, +50%, and +100% weighting. The final result shows that the alternative 19 is still the best alternative on every change in the weighting provided.

The guideline to implementing this alternative also described in order to show that this alternative can be implemented in the real situation. The validation from the officer in the case study company also stated which shown that development in this thesis can contribute the benefits to them in the real situation.

6.2 Recommendation

The 5 years period of evaluating the demand of products was used in this thesis due to the limited information from the case study company. The demand of products after 5 years is blinded. If the demand of products in the next 5 years is the same or decreases, the problem will not occur. On the contrary, if the demand of products in the next 5 years increases, the problem will definitely occur. The warehouses in the case study company might not be able to cope with the increasing demand in the long run so the investment in the new warehouse has to be done. The future work should contain the information about the additional investment in the new warehouse in case that the capacity is not enough concurrently with the the new alternative calculated from the

longer period ex. 10 years if there is a chance to get the information in the longer term in the future.

The period of 5 years study also involved with the life of the warehouse since the warehouse life is normally longer than that. The evaluation when the warehouse was decided to build is no longer realistic. The worthiness of building the warehouse might not the same. Therefore, the consideration of the worthiness of warehouse evaluated by the company in the past should be contained in the future work in order to be used to compare with the other benefits gained whether it still gives the better benefits to the case study company or not.

The information of the inventory turnover ratio is acquired by the case study company. However, this thesis assumes that the inventory turnover ratio in 2010 is the same as in 2015 due to the fact that the case study company tries to maintain the inventory turnover ratio. Nevertheless, inventory turnover ratio has the significant effect to the calculation of the demand of products in the future and it can be changed quite easily. Thus, the future works should concern in this point also.

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APPENDIX:

EVALUATION REPORT FROM INDUSTRY

Evaluation report from industry:

August, 2011

PTT Group solid petrochemical warehouses

Rayong, Thailand

Prepared by:

Rawin Chaiyapin

PTT Group logistics master plan officer

Evaluation report from industry

PTT Group solid petrochemical warehouses

Rayong, Thailand

1. Company Background

From the aspiration of PTT Group to be in Fortune 100, PTT has to increase their revenue up to 150 Billion USD in 2020. Increasing the revenue can be done from 2 main things which are from the new product or the new customer and internal process. Acquiring revenue from the new product or the new customer has to be planned and operated with external factors. However, decreasing operating cost within internal organization process is also importance and has to be done concurrently with the first thing. Cost reduction is used to increase the competitive advantages. PTT Group has been conducted in many dimensions and functions of decreasing operating cost such as reduction in procurement and reduction in operation.

At present, logistics are considered to be the interested topic for businesspersons. Improving logistics in order to gain higher efficiency is the thing businesspersons place an importance on due to the fact that logistics are mostly involved with the internal factors that can be controlled by them. Warehouse management is considered to be the main function of logistics and supply chain that has to be well-managed both in operation and cost management.

Considering warehouse system in PTT Group, warehouse management is still done as a stand alone in each subsidiary company which loses connection and mutual benefits even though the warehouses are the same type that mainly store solid products.

2. Frame work of the study

This study framework in domestic warehouse will contribute benefits to PTT and also brought to the real implementation. This is because this study aims to create value added and do with the existing assets without further investments. Also, fix cost in each company can be capitalized on.

The framework of this study is also conform to the principle of logistics management which are

1) Coordinate end-to-end logistics
2) Control operation expense and working capital
3) Optimal service and reliability
4) Right and efficiency capital expense
5) Most powerful enablers eg. IT, HR, and Infrastructure

For the study framework of 5 years projection plan, I think it is appropriate and accord with the production planning of PTT Group due to the fact that the production plan will be revised every year based on the business environment both internal and external, but the planning will mainly give precedence to 5 years plan.

3. Process and criteria

In addition, in order to manage warehouse to get the best efficiency and suitable for the duty in outbound logistics, evaluating storage capacity that warehouse department has to handle is needed. The assumption using 85% capacity utilization is considered to be an optimal number which PTT Group is also used as the operation framework also. Using 85% capacity utilization is used to buffer the over supply situation that infrequently occur, but using 85% will create the flexibility in warehouse operation and also enhance the ability to support over capacity from the group.

The thesis chose to use phasing out some of the existing warehouses in order to create the most appropriate warehouse management for PTT. This concept can be

brought to the real implementation and considered to have a tendency that PTT Group will be given the benefits more than other concepts due to the fact that this concept creates max utilization without further investments and can also reduce some of costs.

For the consideration in criteria for phasing out some of the warehouses which are

1) Moving and storage cost (33.3%)
2) Internal operation product damage (26.7%)
3) Inventory accuracy (20%)
4) Operational efficiency (20%)

I agree with the selection and the weighting in these criteria. The main activity of warehouse is moving and storage cost due to the fact that it considered being the costs occurred in the warehouse activity so this criteria has to be the first priority. However, good warehouse operation will help creating proper costs and not using costs more than necessity. Moreover, building up system to support working condition is also essential eg. using warehouse applications which all considered to support inventory accuracy aspect. This point of view is the right view that did not place an importance on cost or internal operation as the main. Using inventory accuracy and operational efficiency to support will entirely create the ability to consider efficiency ability and worthiness in selecting warehouses because any warehouse using this methodology as the basis can manage and operate efficiently all the time.

4. Benefits

Cost and benefits evaluation in this thesis are considered to cover all area including reduction in cost of stop operating warehouse and additional cost from the additional resource used for some warehouse that has higher demand of product to be stored.

Transportation cost that will occur since the location of Cherngnern and Maptaphut is quite far away is still incomparable with the overall benefits PTT gains from the selected alternative. This alternative is then considered to be the proper alternative and

worthiness to be implemented. Implementing according to the alternative will produce the good effect in overall efficiency of using cost in warehouse and logistics.

5. Summary

In summary, from the assumption, the screening criteria, weighting, evaluating cost, to developing alternative is considered to be reasonable and considered to be one of the good methodologies which suitable and conform to the objective of the study to find the way to improve and optimize the warehouse in PTT Group in order to gain the best benefits. The way to select the criteria, comprehensive weighting scale and given the importance in every area makes the consideration and analysis correct and perfect. Therefore, the best alternative selected in this thesis is the best alternative in my opinion and possible to implement in PTT Group.

This thesis also builds up the contribution in bringing the knowledge from the research to analyze the context of petrochemical industry in Thailand which will develop the beneficial knowledge to the industrial research in the similar warehouse management.

In managerial contribution given by this thesis, a lot of benefits are given to the person in charge of this area of PTT Group due to the fact that this thesis is the first work that brings the issue of warehouse management in petrochemical products of PTT Group to study with the methodology and the researches which cover all area of warehousing management. Applying the whole part of this thesis or some part of this thesis will certainly bring the warehouse management in PTT Group to be synergized, create the flexibility in supporting production and the sale price, and most important thing is to increase the overall competitive advantage for PTT Group when compared with the competitors in the same industry.

BIOGRAPHY

Ms. Kanteera Tepartimargorn is the author of this thesis. She was born in July 1, 1987. She graduated from Chulalongkorn University in 2009 with a Bachelor degree in Chemical Engineering in faculty of Engineering.