LPG LOGISTICS SYSTEM OF PTT AFTER PRICE FLOATING IMPLEMENTATION

by

Ms. Chermkwan Na bangchang

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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Project Title	LPG Logistics System of PTT after Price Floating Implementation
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The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of the Master of Science in Computer and Engineering Management.

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ABSTRACT

PTT (Petroleum Authority of Thailand) is responsible for serving many petroleum products for Thai people and industries. LPG is one of majority petroleum products. It domestic demand is about 80,000 ton/month. Today, PTT distributes all volume from four supply sources to seven LPG depots located all over the country. The transshipment cost is now compensated from the government because the government would like to fix LPG price uniquely in every location.

However, in the near future the government will announce LPG price floating policy, which will make LPG price of each depot vary. Some of supply sales will move to receive their volume especially from the North and Northeast of the country to the East, Banrongpo depot because of its lower price. The floating price policy and supply sales' behaviors alteration make demands of each depot change, and this situation enables PTT to adjust LPG physical distribution and also some depot facilities.

From overall LPG logistics analysis, PTT is recommended to purchase a new LPG train series in 2003 to haul more volume from the East depot to northern and northeastern depots instead of truck carriage. This investment can save PTT about 0.5-2 million baht/month and also reduce road accidents and traffic problems. For depot facilities, Banrongpo-the East depot- requires additional 500 ton of sphere tanks in 2004, one more truck loading bay in 2006, and from 2004 Banrongpo has to operate in two shifts. Bangkok depot is another depot PTT should concern about LPG storage tank, because its tank space is not enough as theoretical calculation. But the new tank construction in Bangkok area cannot be done because of masses and environmental problems so other alternatives such as volume transferring to the East depot should be created.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table		Page

I. INTRODUCTION

1.1 Overview

Liquid Petroleum Gas (LPG) is one of beneficial energy always used as energy for cooking and heating energy for many industries in Thailand. Currently, Thai government has announced unique price policy for LPG, that its sales price is the same at every depot in Thailand whether it is close or far from supply source. Petroleum Authority of Thailand (PTT), a national energy organization, is responsible for LPG production and distribution throughout the country. PTT transfers LPG to PTTs' customers and other companies such as Esso, Shell, etc. which is called supply sales from four gas separation plants in the East and the South to eight depots located around the country by trucks, tankers (rail) and barges. LPG distribution costs (from gas separation plants or depots to another depot) are compensated from the government, so LPG costs at each PTTs' depots are not different so it is called a unique price.

In the near future, the government plans to drop out the unique price and apply floating price policy to LPG because there is no enough money to repay PTTs' distribution costs. This will make LPG cost at each PTT's depot differ, for example, LPG prices at the North and the Northeast depots are naturally more higher than those in the East because of longer distance from the supply source. Dissimilar sales price may change demand pattern, sales volume of some depots might be grown but some might decline. The main reason is some supply sales who have potentiality may move their truck fleets to receive LPG from the East depot instead of the North and the Northeast. and then, deliver to customers all over the country. This may be reasonable for them to obtain lower price at the East depot; however, they have to deliver to longer distance.

The floating price policy directly affects LPG demand at each depot and the demand change will impact logistics figure and transportation costs as well. Therefore PTT has to prepare action plans in regard to distribution routes, kinds and number of vehicles, and facilities by considering the cost optimization in order to cope with LPG floating price which might happen in the next one or two years.

1.2 Objectives

This project focuses on LPG logistics system after price floating implementation by covering the following objectives:

(1) To forecast LPG sales of each depot in the year 2002-2006 after implementing price floating in the year 2003.

(2) To demonstrate pattern of LPG physical distribution in the year 2002-2006 after implementing price floating in the year 2003 with cost optimization concern.

(3) To search for kinds and numbers of LPG transportation equipment needed to deliver product from supply sources to depots after implementing price floating in the year 2003.

(4) To analyze depot facility sufficiency of all LPG depots in order to serve customer demand in the year 2002-2006.

1.3 Scope

Studying and analyzing a figure of domestic LPG physical distribution of PTT after floating price will be applied with LPG in end of the year 2002 by the government like implementing with oil in the last ten years. The studying will cover through LPG demand of each depot, number and kinds of vehicles needed to transfer LPG from supply sources to destination depots, and also transportation cost comparing with the current figure.

II. LITERATURE REVIEW

2.1 Logistics Development and Growth

The definitions of logistics adopted by some logistics professors were collected by Johnson, James C. (Johnson 1990). Those definitions are as follows:

"The process of planning, implementing, and controlling the effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements."

"Integrated logistics consists of a single logic to guide the process of planning, allocating, and controlling financial and human resources committed to physical distribution, manufacturing support, and purchasing operations."

"The process to develop close, long term and stable relationships with qualified suppliers. As a result, we will all share in the risks and the responsibilities of producing a quality product, at a reasonable cost."

The discussion of the development of business logistics may have led to some unintended conclusions, so some qualifications are probably necessary. First, the areas of marketing, finance, and production are still quite important today. Firms still experience problems in these areas and are continually analyzing and making improvements. What was said earlier merely implies that more progress has been made in improving production, finance, and marketing practices. Second, some firms will not find it in their best interest to focus much attention upon logistics. For example, where transportation, warehousing, and related considerations are a small percentage of total cost, it probably would not be worthwhile to emphasize these areas or spend much time on them. Finally, logistics problems are generally symptomatic of maturity. Therefore,

new firms will generally worry about production and marketing long before they turn their attention to logistics.

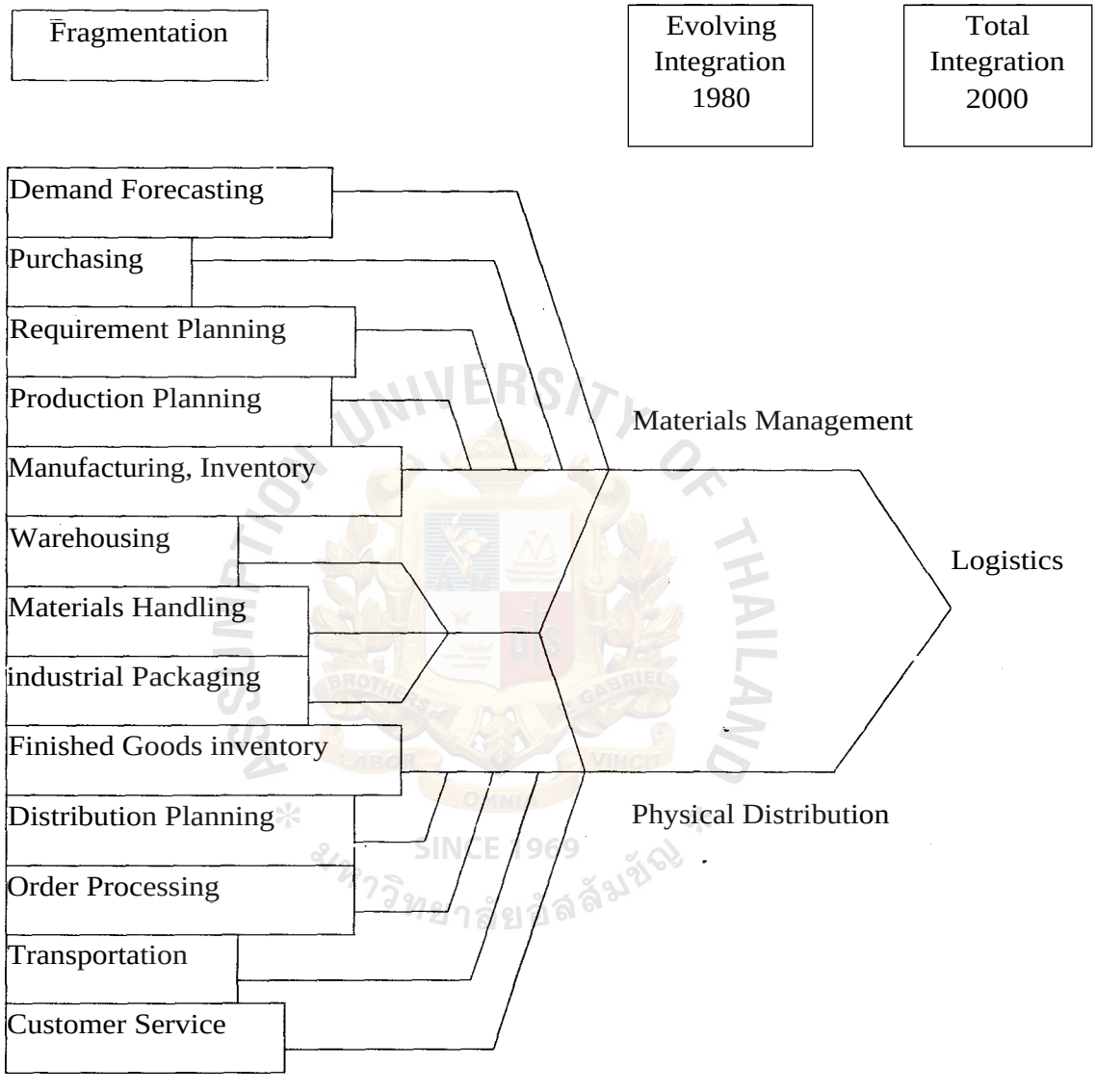

Figure 2.1. The Logistics Evolution (Coyle 1998).

As suggested in this section and the previous one, the interest in logistics has been evolving and developing over time. The development that has occurred in the past 30 years has been remarkable in several ways. One of the most important has been the expansion of activities in the logistics area in many companies. The previous section

noted the materials management versus physical distribution labels. Figure 2.1. shows the evolution that appears to be occurring over time with respect to responsibilities and labels. The use of the term logistics should become commonly accepted by the end of this century (Coyle 1998).

2.2 Logistics Strategy

Selecting a good logistics strategy requires much of the same creative processes as developing a good corporate strategy. Innovative approaches to logistics strategy can give a competitive advantage.

It has been suggested that a logistics strategy has three objectives: cost reduction, capital reduction, and service improvement.

Cost reduction is strategy directed toward minimizing the variable costs associated with movement and storage. The best strategy is usually formulated by evaluating alternative courses of action, such as choosing among different warehouse locations or selecting among alternative transport modes. Service levels are typically held constant while the minimum cost alternatives are being found. Profit maximization is the prime goal.

Capital reduction is strategy directed toward minimizing the level of investment in the logistics system. Maximizing the return on investment is the motivation for this strategy. Shipping direct to customers to avoid warehousing, choosing public warehouses over privately-owned warehouses, selecting a just-in-time supply approach rather than stocking to inventory, or using third-party providers of logistics services are examples. These strategies may result in higher variable costs than strategies requiring a higher level of investment; however, the return on investment may be increased.

Service improvement strategies usually recognize that revenues are a function of the level of logistics service provided. Al though costs increase rapidly with increased

levels of logistics customer service, the increased revenues may more than offset the higher costs. To be effective, the service strategy is developed in contrast with that provided by competition. Proactive logistics strategy often begins with the business goals and customer service requirements. These have been referred to as "attack" strategies to meet competition. The remainder of the logistics system design can then be derived from these "attack" strategies. For example, Domino Pizza was not number one in the pizza market that was serviced by competitors such as Pizza Hut and an army of independent retail operations. It has become America's second-largest pizza chain by promising customers a S3 discount on any pie that takes longer than 30 minutes to be delivered to their home. On the other hand, Frito-Lay developed a strategic advantage with its direct-to-store delivery system, and Atlas Door recognized that there was no company in the industrial door business that could get a door to a customer in less than three months. Atlas stepped in and developed a strategy based on delivering a door in much less time, and it now enjoys a major share of the market.

Each link in the logistics system is planned and balanced with each other in an integrated logistics planning process. See Figure 2.2. Design of the management and control systems complete the planning cycle.

Crafting interesting logistics customer service strategies requires no particular program or technique. It is a simple product of a sharp mind. However, once the logistics service strategy is formulated, the task is then to meet it. This involves selecting among alternative courses of action. Such selection is amenable to various concepts and techniques for analysis. The next section sets the stage for such evaluation. Understanding the logistical alternatives open to the logistician and how they can be evaluated is a recurrent theme throughout this chapter.

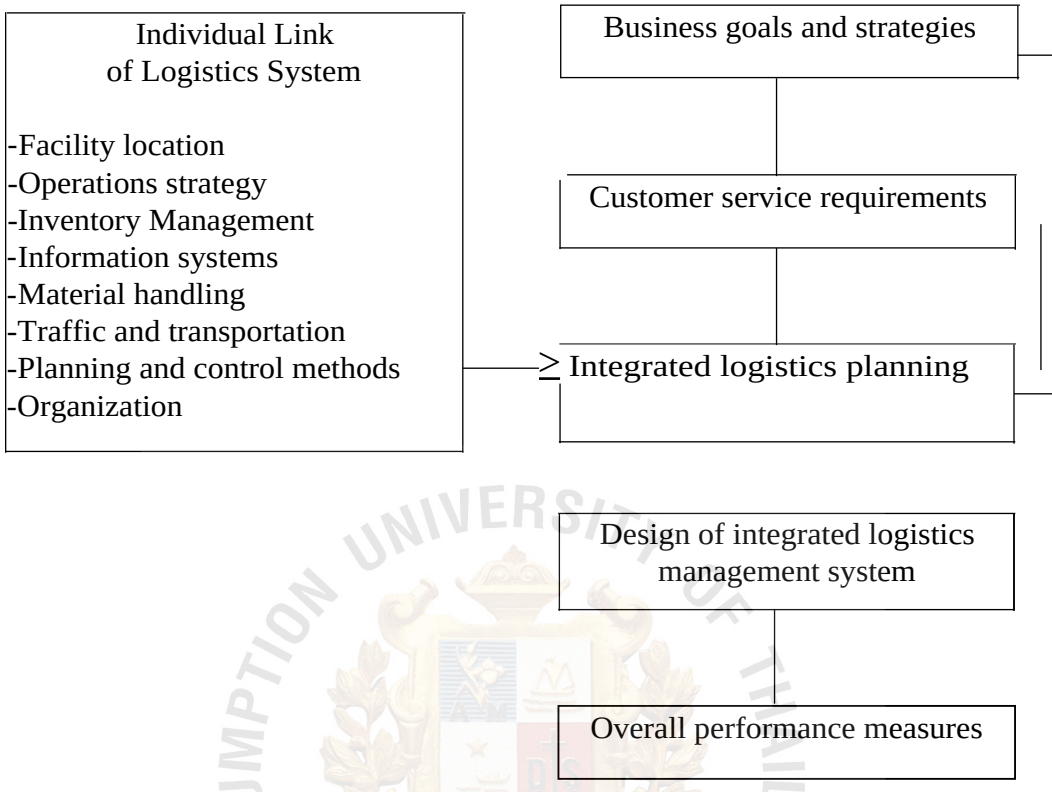

Figure 2.2. Flow of Logistics Planning (Ballou 1996).

2.3 Logistics Planning

Logistics planning attempts to answer the questions of what, when, and how, and it takes place at three levels: strategic, tactical, and operational. The major difference between them is the time horizon for the planning. Strategic planning is considered to be long range, where the time horizon is longer than one year. Tactical planning involves an intermediate time horizon, usually less than a year. Operational planning is short-range decision making, with decisions frequently made on an hourly or daily basis. The concern is how to move the product effectively and efficiently through the strategically-planned logistics channel. Selected examples of typical problems with these various planning time horizons are shown in Table 2.1.

Table 2.1. Examples of Strategic, Tactical, and Operational Decision Making.

Decision Area	Strategic	Tactical	Operational
Transportation	Mode selection	Seasonal equipment leasing	Dispatching
Inventories	Location; control policy	Safety stock level	Order filling
Order Processing	Order entry, transmittal, and processing system design		Processing orders; filling back orders
Purchasing	Development of supplier-buyer relations	Contracting; forward buying	Expediting
Warehousing	Handling equipment selection; layout design	Space utilization	Order picking and restocking
Facility Location	Number, size, and location of warehouses		

Each planning level requires a different perspective. Because of its long time horizon, strategic planning works with data that is often incomplete and imprecise. Data may be averaged, and plans are usually considered good enough if they are reasonably close to optimum. At the other end of the spectrum, operational planning works with very accurate data, and the methods for planning should be able to handle a great deal of these data and still find reasonable plans. For example, we may strategically plan all

company inventories to not exceed a certain dollar limit or to achieve a certain inventory turnover ratio. On the other hand, an operational plan for inventories requires that each item be managed individually.

Logistics planning tackles four major problem areas: customer service levels, facility location, inventory decisions, and transportation decisions, as shown in Figure 2.3. These problem areas are interrelated and should be planned as a unit, although it is not uncommon to plan them singly. Each has an important impact on system design.

2.3.1 Customer Service Levels

The level of logistics customer service to be provided, more than any other factor, dramatically affects system design. Low levels of service allow centralized inventories at few locations and the use of less expensive forms of transportation. High service levels generally require just the opposite. However, when service levels are pressed to their upper limits, logistics costs will rise at a rate disproportionate to the service level. Therefore, the first concern in logistics strategic planning must be the proper setting of customer service levels.

2.3.2 Facility Location

The geographic placement of the stocking points and their sourcing points creates an outline for the logistics plan. Fixing the number, location, and size of the facilities and assigning market demand to them determines the paths by which products are directed to the marketplace. The proper scope for the facility location problem is to include all product movements and associated costs as they take place from plant, vendor, or port location through the intermediate stocking points and on to customer locations. Assigning customer demand to be served directly from plants, vendors, or ports, or directing it through selected stocking points affects total distribution costs.

Finding the lowest cost assignments, or alternatively the maximum profit assignments. is the essence of the facility location planning problem.

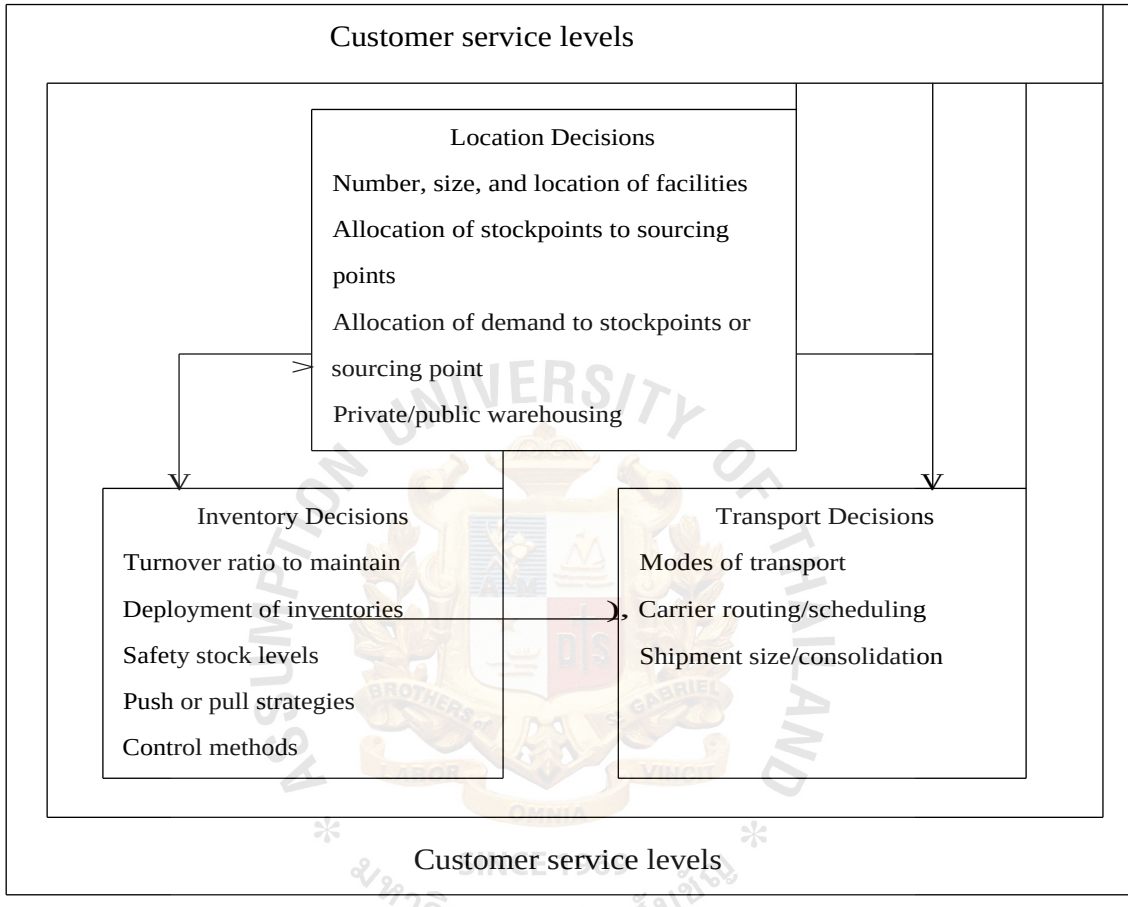

Figure 2.3. Major Strategic Planning Areas with Key Planning Issues (Bailou 1996).

2.3.3 Inventory Decisions

Inventory decisions refer to the manner in which inventories are managed. Allocating (pushing) inventories to the stocking points versus pulling them into stocking points through inventory replenishment rules represent two strategies. Selective location of various items in the product line in plant, regional, or field warehouses or managing inventory levels by various methods of perpetual inventory control are others. The

particular policy that the firm uses will affect the facility location decision and, therefore, must be considered in the logistics strategy (Ballou 1996).

2.3.4 Transport Decisions

Transport decisions can involve mode selection, shipment size, and routing and scheduling. These decisions are influenced by the proximity of warehouses to customers and plants, which, in turn, influence warehouse location. Inventory levels also respond to transport decisions through shipment size (Ronald 1996).

2.4 The Role of Logistics in Profitable Companies

2.4.1 The Value Chain Concept

In Competitive Advantage, Creating and Sustaining Superior Performance, Michael Porter describes how a company can (and does) put generic strategies (cost leadership, differentiation, and focus) into practice. More specifically, he addresses such questions as: How does a firm gain a sustainable cost advantage? How can it differentiate itself from competitors? How does a company choose a market segment so that competitive advantage grows out of a focus-based strategy? When and how can a firm gain competitive advantage from competing with a coordinated strategy in related industries? How is uncertainty introduced into the pursuit of competitive advantage?

Porter asserts that competitive advantage derives from the value a company creates for its buyers. This value may take the form of selling equivalent product at below-competitor prices. Porter uses a tool called 'the value chain' to separate buyers, suppliers and a firm into the discrete, but interrelated, activities from which value stems. The value chain concept may be used to identify and understand the specific sources of competitive advantage, and how they interact. The value chain is, indeed, a concept, but it also is a proven and practical tool for determining how to sustain competitive advantage in an increasingly competitive marketplace.

Why does the value chain theory help us to determine the role of logistics in profitable companies? First, the concept recognizes how the logistics function fits into the business pipeline. In Figure 2.4., which we adapted slightly from Porter, note that logistics represents two of the five primary business activities that add value to a product (or service). We believe that Porter is the first leading business scholar/practitioner to acknowledge this process and link it specifically to competitive advantage.

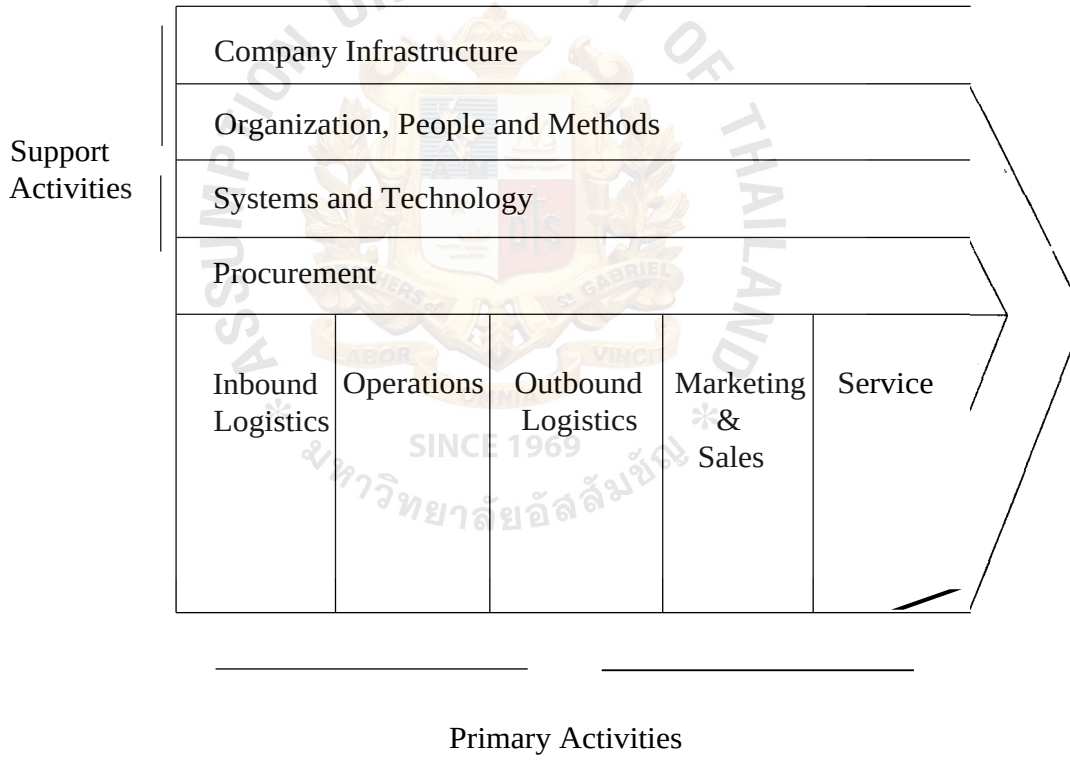

Figure 2.4. The Value Chain (Gattorna 1998).

It is useful to review how Porter defines the five categories of primary activities involved in competing in any industry as follows (Gattorna 1998):

(a) Inbound logistics activities associated with receiving, storing, and disseminating inputs to the product, such as materials handling, warehousing, inventory control, vehicle scheduling, and returns to suppliers.

(b) Operations activities associated with transforming inputs into tl e final product foam, such as machining, packaging, assembly, equipment maintenance, testing, printing, and facility operations.

(c) Outbound Logistics activities associated with collecting, storing, and physically distributing the product to buyers, such as finished goods distribution, warehousing, materials handling, delivery vehicle operation, order processing, and scheduling.

(d) Marketing and Sales activities associated with providing a means by which buyers can purchase the product and inducing them to do so, such as advertising, promotion, sales force management, quoting, channel selection, channel relations, and pricing.

(e) Service activities associated with providing service to enhance or maintain the value of the product, such as installation, repair, training, parts supply, and product adjustment.

2.4.2 Logistical Activities

The definition of logistics or physical distribution presented by the Council of Logistics Management implies activities that could be included as part of the responsibilities of the logistics manager (Ballou 1996). Those activities are as follows:

(a) Transportation

(b) Storage

(c) Packaging

(d) Material Handling

(e) Order Processing

(f) Forecasting

(g) Production Planning

(h) Purchasing

(i) Customer Service

(j) Site Location

There is a general agreement that transportation is a necessary part of the logistics system. A major focus in logistics is upon the physical movement or flow of goods, or on the network that moves the product. This network is composed of transportation agencies that provide the service for the firm. The logistics area would generally be accorded responsibility for selecting a mode or modes of transportation that would be used in moving the raw materials and finished goods of the firm.

A second area, which ties in with transportation, is storage. It involves two separate but closely related activities: inventory management and warehousing. There is a direct relationship between the transportation agency being used and the level of inventory and number of warehouses required. For example, if firms use a relatively slow means of transport, they usually have to keep higher levels of inventory and would usually have more warehousing space for this inventory. They may examine the possibility of using a faster means of transport to eliminate some of these warehouses and the inventory stored therein. As suggested previously, a number of firms have been able to reduce their total logistics cost by increasing the amount of money they spend on transportation to reduce costs in inventory and warehousing. More is said about the inventory area and the interest within the firm about this area in succeeding chapters. At this point, note that there are possible internal organizational conflicts about the level of inventory that should be held and a strong interest in the level and location of inventory

stocks. Also note that there is a very close relationship between transportation and inventory levels, and that if the systems approach is taken, close coordination between these two areas is usually required.

A third general area is industrial (exterior) packaging. It can be demonstrated that the type of transportation selected will have an impact on the packaging requirements for moving the product to the market and also will be important as far as raw materials are concerned. In regard to the product, it is generally conceded that rail or water transportation will require additional expenditures for packaging because of the greater possibility of damage. In the trade-offs analyzed for proposed changes in transportation agencies, we would generally look to see what impact the change will have upon packaging costs. In many instances, when we move to a premium means of transport, such as air, packaging costs will be reduced. Therefore, an argument can be made that packaging should be a part of the responsibility of the logistics area because of this relationship to the transportation agency and also to storage costs.

A fourth area that should be included as a logistics activity is materials handling, which is also of interest to a number of areas in the typical business organization. It should be readily apparent that materials handling is important in the efficient operation of warehouse. Logistics managers are concerned with the movement of goods into a warehouse, the placement of goods in a warehouse, and the movement of goods from storage areas to order picking areas and eventually out of the warehouse to be loaded for transportation. Such activities are affected by materials handling.

Materials handling is concerned with mechanical equipment for short-distance movement, including such things as conveyors, forklift trucks, overhead cranes, and containers. Production managers may want a particular pallet or type of container that may not be compatible with the logistics warehousing activities. Therefore, the

materials handling designs must be coordinated in an effort to make sure that the types of equipment being used are congruous. In addition, the company may find it economical from a purchasing point of view to use the same type of forklift trucks.

Another area of activity that may be specified for control in the logisf cs area is order processing, which generally consists of activities involved with filling customer orders. Initially, one might express some doubt as to why the logistics area would be concerned directly with order processing. However, one important thing on the physical distribution side is the elapsed time between the moment when a customer decides to place an order for a product and the time that those goods are actually delivered in a satisfactory condition.

The initial stage of order processing is concerned with some form of transmittal by the customer, the receipt by the firm of the order, some designation that the order be shipped out, and then the actual transportation of that item. The time lapse with the communications surrounding the processing can be quite significant in some instances. Previous sections discussed trade-offs between transportation agencies and inventory, and recognized the growing pressures of oligopolistic market structures to give good service to customers. Consequently, a company may be forced to use a premium means of transportation, such as motor carrier or air, to meet service requirements. If order processing were a part of logistics, then we might examine possible improvements in order processing that would require additional expenditures but allow us to decrease our transportation costs.

For example, assume that the present system takes a total lead time of eight days for transmittal, processing, order preparation, and shipping. The order processing part of this may take four days, and order preparation may take an additional two days, which means that the goods have to be transported to the customer in two days. The short

delivery time may require premium means of transportation. If order processing is viewed as part of the logistics system, then the company might legitimately lock at improvements in order processing, such as using telephone calls and more computer equipment fc r processing, to reduce order processing time to two days or one day. This would allow tne firm to use less expensive means of transportation and still get the goods to the customer within eight days. Looking at logistics in a time perspective or in terms of total lead time, one can readily see that order processing can be quite important to the logistics function.

Another activity that can be assigned to the logistics area is demand forecasting. One can also question why the logistics manager would be concerned with forecasting. Forecasting of sales is based upon knowledge of the markets as well as upon the manipulation of data with statistical techniques to make a forecast. Sales forecasting is frequently an input to logistics received from marketing in order to facilitate deliveries to various market areas according to the projections. However, logistics managers may need to do their own forecasting for inventory purpose and may use sales forecasts as input.

Another area of growing interest for logistics managers is production planning, which is closely related to forecasting in terms of effective inventory control. Once a forecast is developed, and the current amount of inventory on hand and a usage rate are assessed, the number of units necessary to ensure adequate market coverage can be determined. However, in multiple-product firms, the timing of the productive process and certain relationships in the product line require close coordination with logistics or actual control of production planning by logistics. The integration of production planning into logistics is becoming increasingly common in large corporations such as Kimberly Clark.

Purchasing is another activity that can be included in logistics. The basic rationale for including purchasing in logistics is that there is a direct relationship between transportation cost and geographic location (distance) of raw materials and component parts that are purchased for the production needs of a company. Logistics cost would also be affected by the quantities purchased in terms of transportation cost and inventory costs. Whether purchasing is included as a part of the logistics area is primarily a matter of whether this achieves more effective coordination and lower cost for the firm.

Another area of growing importance is customer service. Customer service is a complex topic and one that other functional areas of the company are also concerned about. Customer service levels are in many ways the glue between many of the other areas of logistics. Decisions about inventory, transportation, warehousing, and so on all relate to customer service requirements. While it is not customary for the logistics area to completely control customer service decisions, there is no question that logistics plays an extremely important role in ensuring that the customer gets the right product at the right place and at the right time.

The last area is plant and warehouse site location. The relevancy of this activity is discussed at some length in later chapters. At this point, the importance to logistics should be readily comprehensible. A change in location could alter time and place relationships between plants and markets or between supply points and the plants. Such changes will affect transportation rates and service, customer service, inventory requirements, and possibly other areas. Therefore, the logistics manager is quite interested in and concerned about location decisions.

2.5 The Transport System

2.5.1 The Basic Modes of Transportation

The basic modes of transportation available to the logistics manager are rail, motor, water, pipeline, and air. Each mode has different economic and technical structures, ar d each can provide different qualities of link service. This section examines the structure of each mode as it relates to the cost and quality of link service possible with the basic modes-the basis for the modal selection analysis (Willis 1990).

(a) Railroads

(b) Motor Carriers

(c) Water Carriers

(d) Air Carriers

(e) Pipelines

All for-hire railroads in the United States are classified as common carriers and are thus subjected to the legal service obligation's discussed later. Since no legal restraints (Interstate Commerce Commission regulations regarding operating authority) are imposed upon railroads regarding the types of commodities to be transported, railroads have a distinct advantage as to availability and capability of providing service to "all" shippers. This is not to imply that railroads can transport any product anywhere, for there are limitations upon the accessibility of rail transportation. But with respect to the ability to transport a wide variety of goods, the railroads have a distinct advantage over other common carriers in the different modes.

Market structure: The limited number of rail carriers is attributed, in part, to the economic structure of this mode. Railroads fall within that infamous group of business undertakings labeled as "natural monopolies." A large investment (in terminals, equipment, and trackage) is necessary to begin operation, and the accompanying huge

capacity capable with this investment results in the railroads being a decreasing cost industry. As output (ton-miles) is increased, the average per-unit cost of production decreases. Thus, it is economical and beneficial to society to have fewer railroads in operation in a given area, and to permit those few firms to realize the economies inherent with large-scale output. To ensure that the railroads do not abuse this monopolistic situation by charging very high prices (rates), all railroads are regulated as common carriers and are required to charge reasonable rates for nonexempt moves.

Distance and volume: A major advantage of using railroad transportation is the long-distance movement of commodities in large quantities at relatively low rates. Products of forests, mines, and agriculture are the major products transported by railroads. These products are characterized by low value and high density, and transportation costs account for a substantial portion of their selling price.

Service characteristics: Low accessibility is one primary disadvantage of rail transport. Accessibility refers to the ability of the carrier to provide service to and from the nodes in a particular situation. A rather long transport time is another area where rail transport stands at disadvantage. The average speed of a boxcar is approximately 20 miles per hour, even though speeds of 50 to 60 miles per hour are attainable on the "open" track. The problem occurs in the classification yard, where boxcars are consolidated, marshaled into train units. This huge physical task requires the consolidating boxcars going in a similar direction, and the breaking out of cars that have reach their destination or that must be transferred to another train unit going toward the ultimate destination of their shipments. This function adds to the overall slow speed of rail transport.

Other service qualities of importance to the logistics manager-reliability and safety-are favorably provided by railroads. Weather conditions are not as disruptive to

rail service as to the service of other modes, and thereby cause minor fluctuations in transit time reliability. The movement of goods by rail transport requires considerable packaging and resultant packaging costs.

Today's railroad industry is undergoing considerable change in response to the economy and deregulation. Traditional railroad markets (e.g., steel and mining) are depressed, causing rail traffic from these market segments to decline or, at best, to remain stagnant. In addition, deregulation has increased the competitive pressures for railroads to lower rates, and the railroads have responded through the contract rate-making provisions of the Staggers Act.

Secondly, the motor carrier is very much a part of any firm's logistics system; the motor truck, from the small pickup truck to the largest tractor-semitrailer combinations, is utilized in some capacity in almost every logistics operation. The United States' sophisticated network of highways permits the motor carrier to reach all points of the country. Therefore, the motor carrier is capable of providing transportation service to virtually all shippers. .

Market characteristics: The regulated motor carriers consist of a large number of relatively small firms. This large number of carriers is due in part to the low capital requirements for entry into the trucking business. The cost structure is characterized by high variable cost and low fixed cost. The motor carrier does not require extensive investment in terminals and equipment, and does not invest in its own highway. The highway is built and maintained by the government, with the motor carrier paying for this on a use basis-through highway use taxes, licenses fees, and so on. These expenses are variable and thus contribute to the high-variable-cost structure.

Service characteristics: The regulatory controls regarding the commodities transported and the areas served have a direct bearing upon the accessibility of

particular carriers. But the major advantage of motor transport over other modes is its inherent ability to provide service to any location. Truck transportation is not restricted to providing service to customers located adjacent to a track, waterway, or airport. Motor carrier operations do not involve coupling trailers together to thin' long "train" units, because each cargo unit (trailer) has its own power unit and can be operated independently. Thus, on truckload movements, the shipment goes directly from the shipper to the consignee, bypassing any terminal area and time required for consolidation. Such technical and operational characteristics enable the motor carrier to provide relatively low transit times (lower than rail and water, but higher than air).

Weather conditions and traffic conditions existing on the highways can cause disruptions in motor service and thus affect transit time reliability. These factors affect the dependability of all motor carriers. The reliability of a specific carrier is related to the degree of operating efficiency achieved for a given link, and may vary among links for a given carrier. The other relevant service attribute, safety, is difficult to generalize upon. The packaging required for motor carrier movements is less stringent than that required for rail or water; this results from the use of pneumatic tires and improved suspension systems that make the motor carrier ride quite smooth. Again, the degree of safety occasioned by a particular carrier for a given link is dependent upon the actual operations of individual carriers.

The relatively high cost by motor carrier must be considered. This again suggests that commodities moved by truck must be of high value to sustain the transportation costs, or that the trade-offs (savings) of inventory, packaging, warehousing, or customer service costs must warrant the use of this higher-cost mode.

The competitive environment has been a mixed blessing to shippers. On the positive side, lower motor carrier rates have enabled shippers to reduce transportation

costs and improve profitability. On the negative side, the downward pressure on rates has contributed to carrier bankruptcies (recent examples include McLean Trucking and Hall's Motor Freight). These have caused disruptions to a firm's logistics operation that range from minor delays in delivery of freight in the bankrupt carrier's system to a temporary halting of the film's transportation function until a replacement carrier is found for a key link provider.

Thirdly, water transportation has been a major factor in the development of the United States, and remains an important factor in today's economy. In the early stages of U.S. development, water transportation served as the only means of connecting the United States to Europe, which was the market area for U.S. agricultural production and the source of manufactured goods. Thus, many larger, industrial cities are located along major water transport routes.

Service characteristics: Water carriers are primarily long-distance movers of low-value, high-density cargoes that are easily loaded and unloaded by mechanical devices. Mineral, agricultural, and forest products are- the major commodities transported. These products are shipped in large quantities, as evidenced by one barge's capability to transport about 1,500 tons. The average length of haul is 459 miles for internal water carriers, 516 miles for Great Lakes carriers, and 2,095 miles for coastwise and intercoastal carriers.

The principal advantage of using water transport is its low cost. Thus, water transport is most advantageous for commodities with a low value-to-weight relationship, or for commodities in which the transportation cost is a significant portion of the selling price. In return for this low rate, the shipper receives a slow method of movement. Possibly water transport provides the highest transit time of all modes. Internal and Great Lakes operations are affected by weather conditions-ice and low

water levels cause disruption in service. In addition, the accessibility of water transport is greatly restrained. Only shippers adjacent to the waterway can use water transport directly. In other situations, the use of water carriage requires a prior or subsequent movement by land transport. Thus, the major disadvantages of water transport are long transit times and low accessibility.

Passenger movement is the principal business of the air carrier; passenger revenue accounts for the majority of air carrier business. In the movement of freight, air transport is in somewhat of an infancy stage; it accounts for less than 1% of the total intercity ton-miles of freight.

Cost characteristics: The cost structure of the air carrier consists of high variable costs in proportion to fixed costs, somewhat akin to the motor carrier cost structure. Like motor and water carriers, air carriers do not invest in the highway (airway). Terminals are built by the government, and lease payments and landing fees are paid for their use; these costs are variable. Although the equipment cost is quite high, it is still a small part of the total cost.

Freight movement by the major commercial air carriers started as a by-product of the passenger business. Excess capacity existed in the "belly" of the plane and thereby offered potential for the movement of freight. Cargo was moved as incidental to the primary movement of passengers. As cargo demand grew, the carriers began to give serious consideration to this business arena. Now, the scheduled carriers have dedicated equipment specifically to freight movement, and have developed and operated freight service to meet the ever-growing needs of freight shippers. The all cargo lines have always concentrated upon cargo transportation.

Service characteristics: The major advantage of using air transportation is speed. Air transport affords a distinct adva stage in low transit time over long distances. Thus,

air transport is a necessary means of movement for emergency shipments or shipments that have a high degree of perishability both in the physical sense of spoilage and in the service realm of lost sales or productivity.

Cost is the major disadvantage of using air transportation, and it precludes many shippers from utilizing this mode. Commodities with high value-to-weight relationships can sustain this high transport cost. For such commodities, air transport is a viable transport method because transportation is a smaller portion of the selling price than is inventory holding cost. In this shipping situation, the logistics manager can reduce inventory levels and inventory costs, and rely upon the speed of air transport to meet nodal demand.

Accessibility of air transport is somewhat limited. Most firms using air carriers must rely upon land carriers to make the freight available at the airport. The reliability of air transport is also somewhat of a disadvantage. Air service is subject to interruptions caused by weather conditions. These conditions result in increased transit time and adjusted higher inventory levels. But with the advent of instrument flying and the adoption of these devices at a greater number of airports, this interruption in service is decreasing to a minimal amount.

The pipeline industry refers to oil pipelines and not natural gas pipelines. All oil pipelines, of which there are approximately 140, are regulated by the Federal Energy Regulatory Commission. Natural gas pipelines are regulated by the Federal Energy Regulatory Commission, the same as any public utility.

Market structure: The pipeline is not an acceptable method for moving general commodities; rather, its use is restricted to the movement of liquid petroleum products. Pipeline accessibility is limited. Only shippers adjacent to the pipeline can use this mode directly. For shippers not located adjacent to the pipeline, another more

accessible mode (truck, water, and railroad) is required to transport products to or away from pipeline. The speed is quite slow, typically less than 10 miles per hour, resulting in long transit miles; however, pipeline service is not subject to disruptions due to water conditions.

Cost characteristics: The pipeline cost structure is one of high fixed costs and low variable costs, quite similar to that existing railroads. The investment in the line, terminals, and pumping stations is the major factor contributing to this cost structure. Low cost, as compared with other modes, is the major advantage to using oil pipelines. However, the inability to transport solids limits its usefulness in the logistics system of a firm manufacturing durable goods.

2.6 Forecasting Demand

A forecast is an inference of what is likely to happen in the future. It is not an absolutely certain prophesy. Even very carefully prepared forecasts can be wrong. In fact, it is extremely rare for a forecast to be exactly right. Even though forecasting efforts are not 100 percent accurate, they should not be neglected, they should not be neglected, because forecasting is very important.

In addition to being an important input for long-rage, strategic decisions, forecasts are an important basis for shorter-range decisions in day-to-day operations. Businesses must develop forecasts of the level of demand the company should prepare to meet. Since service operations generally cannot store their outputs as inventory, they must try to estimate the level of future demand so they can have the proper amount of service capacity. If they overstaff they waste resources or if they understaff, they may lose business, time, customers, and their overworked employees.

Table 2.2. Type and Characteristics of Forecasts.

Range of Forecast	Representative Horizon, or Time Span	Applications	Characteristics	Forecast Methods
Long	Generally up to 5 years or more	Business planning: Product planning Research programming Captial planning Plant location and expansion	Brpad. General Often only qualitative	Technological Economic Demographic Marketing studies Judgment
Inter-mediate 1	Generally up to season to 2 years	Aggregate planning: Capital and cash budgets Sales planning Production planning Production and Inventroy budgeting	Numerical Not necessarily at the item level Estimate of reliabiltiy needed	Collective opinion Time series Regression Economic index correlation or combination Judgment
Short	Generally less than 1 season: 1 day to 1 year	Short-run control: Adjustment of Production and Employment levels Purchasing Job scheduling Project assignment Overtime decisions	May be at item level for planning of activity level Should be at item level for adjustment of purchases and inventory	Trend extrapolation Graphical Explosion of short-term product or procuct family forecasts Judgment Exponential smoothing

Various considerations in regard to forecasting are presented in this part, along with a discussion of several methods and models commonly used in forecasting. The primary focus is on demand forecasts, because demand directly affects the plans and decisions within the operations function. Some of the characteristics of forecasts with different horizons and some decisions based on these types of forecasts are shown in Table 2.2.

A large number of factors influence demand, see Figure 2.5., particularly when one considers secondary influences, that is, factors that affect the customer's demand for goods and services, which in turn affects demand for the company's product or service. Figure 2.5 shows schematically some of the factors that affect demand.

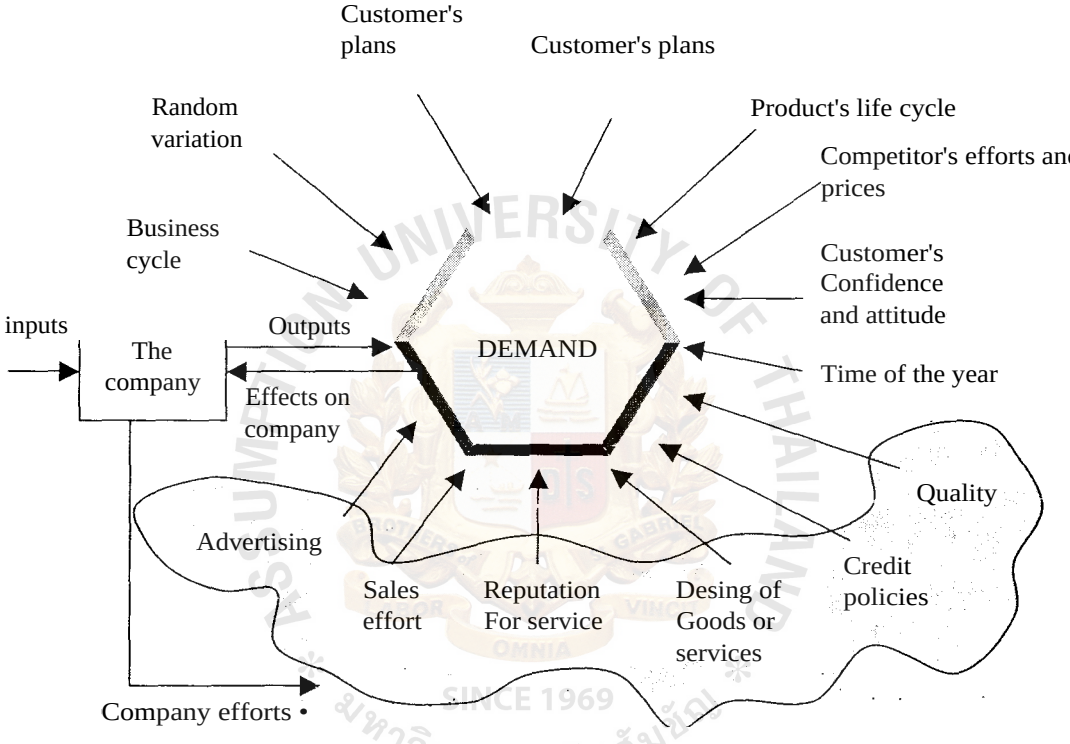

Figure 2.5. Some Foctors That Affect Demand for a Company's Product or Service (Dilworth 1998).

As mentioned earlier, a forecast can be developed through either a subjective approach or an objective, quantitative approach. Forecasting methods are grouped into two major categories, depending on whether the demand estimate is developed solely on the basis of subjective opinion or through the use of some mathematical formula - a quantitative approach. Methods in the first group are called subjective, qualitative, opinion-based, or judgmental forecasts and are discussed in the next section.

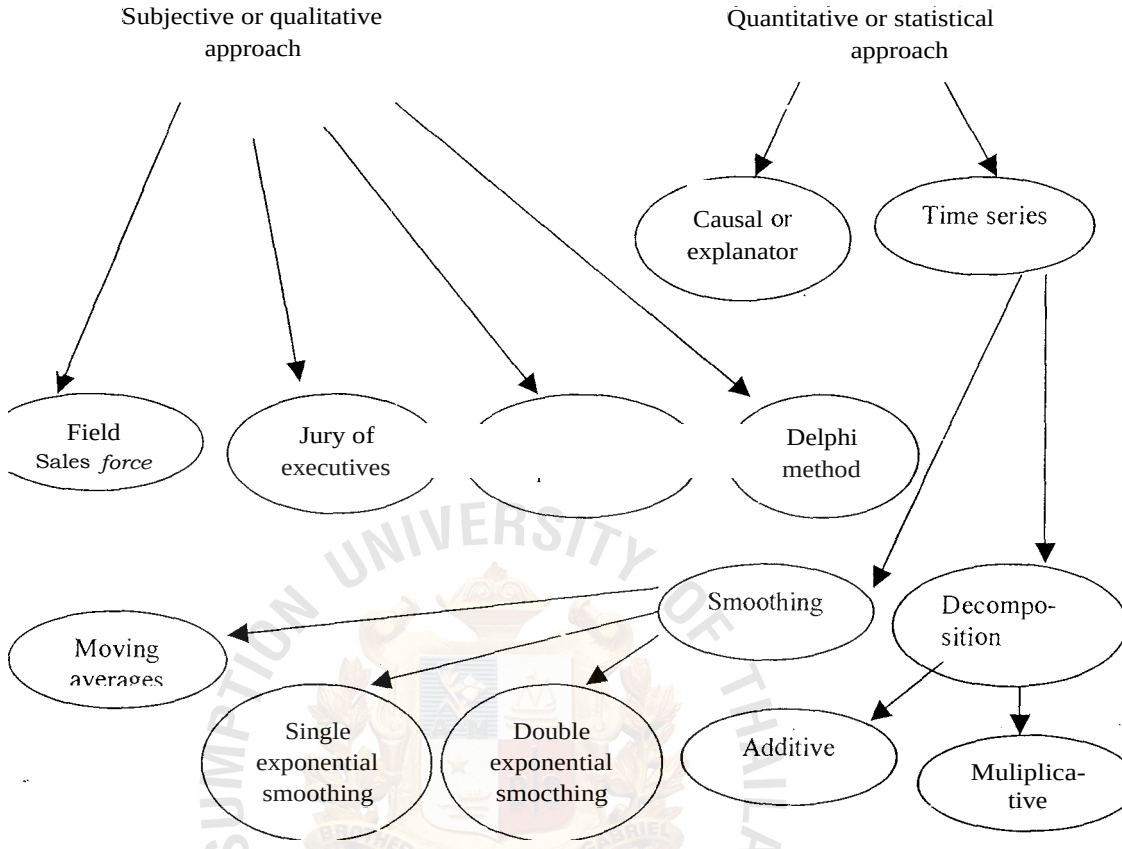

Figure 2.6. Breakdown of Forecast Methods or Models (Dilworth 1998).

Following the section on subjective forecasting methods is a discussion of several methods that are developed through a quantitative or mathematical approach. These are called quantitative or statistical forecast methods or models. Statistical forecast methods can be further subdivided on the basis of the variable or variables that are considered to be related to demand and used to predict future levels of demand. In one subgroup, called time series models, time is the only independent variable used to forecast demand. The other subgroup consists of causal or explanatory models that use one or more other variables instead of, or in addition to, time as a basis for forecasting demand.

A further breakdown of this group into specific models is shown in Figure 2.6. The methods and models shown in this figure are discussed in the material that follows.

2.6.1 Subjective Forecasting Method

Certainly the simplest and sometimes the fastest meth ds involve only subjective opinion, without expressing the forecast in mathematical formulas. Of the many possible subjective methods, we consider four. Each method uses a different source for the subjective opinion.

(a) Field Sales Force

(b) Jury of Executives

(c) Users' Expectations

(d) Delphi Method

The first subjective forecasting method is that of having each sales representative estimate the sales within his or her territory. The estimates are combined and reviewed at successive levels of the management hierarchy so that the opinions of the district managers and the sales managers are also incorporated.

Forecasts of this nature have several advantages. One is that they are easily divided by terriory, branch, sales representative, or product. The sales representatives may be more highly motivated when they have a feeling of participating in the planning process. This method provides input from persons in direct contact with the customer. A method such as this is more suitable for a new product.

Since this is a subjective method, it has the disadvantage of being subject to individual biases. Sales representatives may be unduly influenced by recent market responses. If the sales performance goals are based on the forecast, sales representatives may be tempted to underestimate. If the forecast is a basis for the allocation of some scarce products, sales representatives may overestimate.

The second subjective forecasting method involves the averaging of independent estimates or a discussion by a group of executives that results in a single estimate. Sometimes one senior officer reviews estimates from sales, production, and finance executives and applies his or her judgment to arrive at a single estimate.

An advantage of this method is that it can provide a forecast in a relatively short time. It also brings a variety of viewpoints to bear on the subject and can foster team spirit.

This method, however, requires the time of highly paid executives. It is more difficult to develop breakdowns by territory, district, sales representative, and product . It is also subject to biases due to individual attitudes and situations.

A company may seek subjective opinions from people outside the organization. One such method is the users' expectations method. Sales representatives may poll their customers or potential customers about their purchasing plans for the future. Mail questionnaires or telephone surveys may be used to obtain the opinions of existing or potential customers.

An advantage of this method is that it provides the forecaster with an opportunity to learn some of the thinking behind the customer's intentions. The forecaster may obtain users'views of the product's advantages and weaknesses as well as insight into the reasons why some consumers are failing to buy the product. Such information makes this method useful in planning product improvements or product developments.

One potential disadvantage of the users' expectation method is that it may annoy some highly valued customers. This method commands more confidence than it may warrants because customers' buying expectations are based on their forecasts, which are also subject to change and error. This method of forecasting often requires considerable time and a large staff.

When several knowledgeable persons are asked to provide subjective estimates of demand or forecasts of probable advances in technology, several opinions are likely to emerge. In such circnistances, one has to determine which opinion to accept or how to bring the group to a consensus. The Delphi method is a systematic means to obtain consensus from group or panel of experts. The panel does not meet as a committee to discuss, debate, or persuade. Panel members usually are kept separate and asked not to confer. Preferably, the membership is not revealed to the panel. This measure is intended to evoke each member's unbiased opinion by preventing the influences of group dynamics. Otherwise, members may feel pressured to yield to a socially dominant individual or may fear loss of face if they back away from a publicly stated opinion. A panel coordinator contacts each participant, usually by a mail questionnaire.

Care should be taken so that the initial questionnaire avoids ambiguity and fully explains the matte]. about which an opinion is being sought. Otherwise, a diverse group of people who never meet to discuss the issue may reach divergent conclusions as to just what the issue is. The experts send their opinions to the panel coordinator, who tallies the results. If opinions differ significantly, another round of responses is solicited. The coordinator reveals the results of the previous tally to the panel members without identifying the holders of the opinions. Members whose opinions differed from, say, the middle 50 percent of the estimates are asked to reconsider their opinions and to offer a written rationale if they feel that an estimate outside this range is still appropriate. Additional rounds of estimates can be obtained until the panel closes in on a value or a range that is narrow enough to be useful as a forecast or consensus on the matter under consideration.

The Delphi method is the last subjective forecasting technique we will discuss. We now move into an overview of the quantitative forecasting methods, after which we will discuss specific quantitative models in considerable detail.

2.6.2 Quantitative Forecasting Methods

Quantitative forecasting methods use a mathematical expression or model to show the relationship between demand and some independent variable or variables. There are two major types of quantiative forecasting models: time series models and causal models. Time series models use time as the independent variable and project the "demand pattern" (that is, the past relationship between demand and time) to estimate demand in the future. Causal models, sometimes called "associative models" or "explanatory models," use some independent variable or variables instead of, or in addition to, time, which demand has tended to show a consistent relationship in the past. Values of the independent variable(s) are used to calculate the future value of demand that the model predicts. Of course, for the model to be useful as a forecasting tool, changes in the independent variables must take place with sufficient lead time before the associated changes in demand. (These variables are also called leading indicators.)

Use of either of the two types of quantitative models (time series or causal) as a forecasting tool rests on an assumption of continuity. That is, one assumes that the type and degree of relationship between demand and the independent variable(s) that existed in the past will continue in the future. We do not have to understand why the relationship exists, but for the model to work, the relationship must continue to follow the model if the model is to be a useful forecasting tool. As we begin to consider relationships that might exist in the demand data we should first mention some preliminary steps in analysis of demand data.

The effects of any unusual or irregular event that caused a change in demand and is not expected to recur at regular times in the future should be removed from the data. Examples of this type of event are the effect on motel and restaurant sales near the sites of the Olympics or World Series or unusually high demand because of a strike or natural disaster at a competitor's business. Irregular events of this nature distort the demand pattern that would normally exist.

Often it is helpful to make a graphical display of the data to see if a pattern is present that may help to predict future values. The components of a pattern that the forecaster may look for in the data are discussed in the next section.

Components of a Time Series

Time series models often are adequate forecasting tools if demand has shown a fairly consistent pattern over time and the conditions under which the pattern has occurred are expected to continue. A time series is a sequence of data collected at intervals of time and arranged in the order of their occurrence. A chain of daily, weekly, or monthly sales data is an example of a time series. Such a series may have a fairly consistent pattern that repeats over time. Sometimes a pattern is not apparent in the raw data, but the data can be decomposed into components that show a pattern which is helpful in projecting the data. Four commonly recognized components of a time series are its trend, seasonal, cyclical, and random components.

(a) The trend component is the general upward or downward movement of the average level of demand over time.

(b) The seasonal component is a recurring fluctuation of demand above and below the trend value that repeats with a fairly consistent interval. Demand for many products or services is weather-related and repeats a genetral

pattern each year. Seasonal patterns, however, can repeat weekly, monthly, or with some other interval.

(c) The cyclical component is a recurrent upward and downward movement that repeats with a frequency that is longer than 1 year. This movement is usually attributed to business cycles. (inflation, recession, etc.), so it may not have a consistent period of repetition. As many as 15 or 20 years of data may be required to deterniine and describe the cyclical component.

(d) The random component is a series of short, erratic movements that follow no discernible pattern.

Of the four components in a time series, Random variations, by definition, are unpredictable, sc they are not identified. Cyclical variation requires many years of data to determine its degree and repetitiveness. Demand data for the same product are seldom available for sufficient years to permit the effects of cyclical variation on demand to be identified. Fortunately, most operations decisions do not require enough lead time for cyclical variations to have serious impact. Long-range decisions for distant time periods are usually general plans that will be revised and refined as those time periods draw closer. Consequently, the cyclical component will not be isolated. One should recognize that a trend estimate may be somewhat high if it is estimated from data that were collected during a rising business cycle and somewhat low if estimated from data collected during a decreasing cycle. Even without this possibility, a large element of uncertainty is associated with a trend projected very far into the future.

2.6.3 When Various Models Are Appropriate

The model that is appropriate for forecasting a demand pattern depends on the demand pattern to be projected and the forecaster's objectives for the model. This part

briefly discuss the situations in which each model may be used before going into the details of how to calculate a forecast with the model.

(a) Time Series Smoothing

(b) Time Series Decomposition

(c) Causal Models

(d) Time Series Smoothing

(e) Simple Moving Average

(f) Weighted Moving Average

(g) Single Exponential Smoothing

(h) Causal Models

(i) Regression Methods

Firstly, when the random component of a time series has fluctuations that deviate substantially from the average level of demand, it is often useful to smooth out the data by averaging several observationg to make the basis pattern more apparent. Four averaging techniques—the simple moving average, weighted moving average, single exponential smoothing, and double exponential smoothing—are discussed in the chapter. In general, the first three techniques are appropriate to produce final forecasts only if the data exhibit not trend, that is, if the slope is horizontal. Double exponential smoothing is an averaging technique that can be used to identify and project a trend when the general level of demand is changing over time.

Secondly, time series decomposition is more appropriate if seasonal variation is evident in the demand pattern and the effect of seasonality is to be included in the forecast. Time series decomposition can be used when the general trend in the demand pattern is horizontal and when it is not. The concepts of both additive and multiplicative seasonal variation are discussed after the smoothing models are presented.

Thirdly, sometimes demand does not exhibit a consistent pattern over time because the level of one or more other variables that have an effect on demand has changed during the period when the demand series was collected. If a forecast is to be made for periods during which the levels of some of these variables may be changed, the effect of these variables must be identified and used to predict future demand. Causal or explanatory models are useful for the purpose. A very extensive search may be required to identify variables, or combinations of variables, whose change precedes changes in demand and with which demand tends to be correlated consistently. If such variables can be found, one can use values of the variables to predict future levels of demand. Models that may be used to determine and project the relationship among the causal variables anad subsequent levels of demand include linear regression, curvilinear regression, and multiple regression. Use of linear regression as a causal model is briefly introduced near the end of the chapter.

Fortnly, the above discussion has presented some general characteristics of time series and causal models and when each may be used appropriately. By looking at the demand pattern, a forecaster has some idea of the types of quantitative models to try to see which fits the demand data better. In evaluating and comparing forecast models, it is desirable to use some quantitative measure of forecast accuracy. The next section discusses some quantitative measures that can be used to measure the accuracy of forecast models to see which appears to do the best job of fitting the demand data. We begin our discussion with the simple moving average. Other smoothing models discussed in this section are the weighted moving average, single exponential smoothing, and double exponential smoothing. After this section, time series decomposition is discussed, followed by causal models.

Fifthly, a simple moving average is a method of computing the mean of only a specified number of the most recent data values in series. Assume, for example, that we were keeping records of monthly sales. We might compute a 3-month moving average at the end of each month to smooth out random fluctuations and get an estimate of the average sales per month. This number would be useful to see if the average had increased or decreased since some prior period. A moving average is also useful for other reasons. If there is no noticeable trend or seasonality in the data, the moving average gives a forecast of the mean value of sales in future periods. A moving average can be used to average out seasonality if the number of periods included in the average is equal to the time required for the seasonal pattern to start to repeat itself—that is, 12 months of monthly data, four quarters of quarterly data, and so on, if the seasonal pattern repeats each year.

To compute a 3-month moving average, at the end of each month we add sales for the latest 3 months and divide by 3. If we want a 4-month moving average, at the end of each month we sum sales for the latest 4 months and divide by 4. At the end of a period t, the n-period simple moving average (SMA), which might be used as a forecast for period t + 1 if the mean is not changing over time, is given by equation 2.1.

$$\boxed{SMA_{t+1} = (1/n) \sum A_i} \qquad (2.1)$$

where SMA_{t+1} = simple moving average at end of period t (it might be used as a forecast for period t +1.)

= actual demand in period I

n = number of periods included in each average

Averaging multiple periods helps to smooth out random fluctuations so that the forecast or average has more stability. Stability is the property of not fluctuating erratically so that the forecast moves in a way consistent with the basic demand pattern. Gaining stability is an advantage if the degree of random fluctuation in the demand data is high. A moving average will gain stability if a greater number of periods in the average is too great, the average will be so stable that it will be slow to respond to nonrandom changes in the demand data.

Responsiveness is the ability of a forecast to adjust quickly to true changes in the base level of demand. Both stability and responsiveness are desirable in a forecast. Unfortunately, these two characteristics are in conflict. Several demand periods are required to deteimine whether the new level of demand is persisting or whether a change has been just a random fluctuation. If a forecast is changed in immediate response to each change in actual demand, it will also respond to random fluctuation. If a demand pattern is knoWn to have relatively small random fluctuations about some fairly stable level, then a responsive forecasting method should be used to smooth these erratic ups and downs. If a demand pattern is known to have large random fluctuations, then a stable forecasting method should be used. Both responsiveness and stability are difficult to achieve with a forecasting method that looks only at the series of past demands without considering factors that may have caused a change in that pattern. Naïve forecasting methods alone do not take into consideration the external causative factors.

Sixthly, equal weights were assigned to all periods in computation of the simple moving average. The weighted average assigns more weight to some demand values (usually the more recent ones) than to others. The rationale for varying the weights is usually to allow recent data to influence the forecast more than older data. If there is a

long-run trend in demand, a weighted average, but it will still lag behind demand. We cannot average the past sales values and get a higher value than any past sales value, which is what we desire when we are trying to project tile next value in a continuing upward trend. A method of adjusting for the presence of a trend in demand data is discussed later.

Seventhly, another form of weighted moving average is the exponentially smoothed average. This method keeps a running average of demand and adjusts it for each period in proportion to the difference between the latest actual demand figure and the latest value of the average. If the single smoothed average at period t is used as the forecast for the next period, SF_t+1, equation 2.2a or 2.2b can be used to calculate the forecast. Equation 2.2b is often preferred if one wishes to calculate a measure of forecast error because the error is shown in parentheses for each period.

$SF_{t+,} = ocA_t + (1-0c)\ SF_t$ [2.2a]

$SF_{t-1} = SF_t + cc\ (At - SF\ t)$ [2.2b]

where SF_{t+i} = simple smoothed forecast for time period following period t

SF , = smoothed average forecast for period t

cc = smoothing constant that determines weight given to previous data (0: cc 1)

A_t = actual demand in period t

The smoothing constant cc is a decimal value between 0 and 1. Often it is set at a value that produces forecasts that fit past data better than forecasts computed with any other value of oc. It also influences the stability and responsiveness of the forecast.

Examination will show that if oc were set to equal 0, the old occurred. This would result in a perfectly stable forecast, but it would not respond in any way to changes. If cc were set to equal 1, the latest forecast would equal the last actual value—very responsive but not stable if there is any random fluctuation in the data. Values of oc between 0.1 and 0.3 are often used in practice.

Eighthly, the time series analysis method of forecasting and the averaging methods presented previously used time as the only independent variable. However, the use of time alone does not provide a means to identify turning points that are not inherent in past patterns. The time series analysis forecasting method used time as the independent variable (X axis) and demand as the dependent variable (Y axis). Some forecasting methods use other independent variables to assist the forecaster in estimating future demand. Such methods allow forecasters to use some of the factors they probably would consider if they were making subjective forecasts.

Ninthly, we may want some measure of external conditions, such as an economic indicator, as the variable to explain demand. The Federal Reserve Board, the Department of Commerce, and many other government agencies publish values of economic indicators. Trade associations, local planning commissions, licensing agencies, and banks also have information related to a company's sales.

_ The objective is to find an available indicator that moves before the company's sales change (a leading indicator) and that has a sufficiently stable relationship with sales to be useful as a prediction tool. Linear regression is a means of finding and expressing such a relationship. Simple linear regression fits a line to a series of points that inpast values of one dependent variable (sales) and one independent variable (the indicator). Often the method of least squares is used to fit the line to the data points so that the sum of all the squared deviations from the points to the line will be minimized.

Probably the use of other variables in addition to an economic indicator (for example, advertising expenditures or the price of the good or service) will better explain sales. Multiple regression involves the establishment of a mathematical relationship between a dependent variable and two or more independent variables. The complexities of multiple regression are beyond the scope of this book, but an example of simple linear regression provides a general introduction to the concept. The method of least squares is used to fit the line to the data in this example. The least-squares method was also mentioned as a way to estimate the trend line in time series analysis (Dilworth 1998).

III. THE EXISTING LPG LOGISTICS SYSTEM

In the previous ch2pter, it is described that PTT has a major authority to serve people in every location with many petroleum products such as fuel oil, Liquid Petroleum Gas (LPG), Natural Gas Liquid (NGL), etc. For LPG, PTT transfers it from supply sources to all LPG depots to match with the demand in each area. Transportation cost occurred from LPG transshipment (supply sources to PTTs' depot) is compensated from the government, so today LPG price at every depot is unique.

3.1 LPG Supply and Demand

Currently, Thailand has four LPG supply sources. The first and the second one belong to PTT, and they are located in Rayong called Rayong gas separation plant and in Nakornsrithummaratch called Khanom gas separation plant, respectively. The third one belongs to Shell called Thai Shell plant located in Kumpangpetch province, and the forth LPG supply source is refinery group, Thaioil and Rayong refinery! These four plants can produce 137,000 ton/month of LPG as their current maximum production capacities. Maximum production capacity of each plant is shown in Table 3.1.

Table 3.1. Maximum Production Capacity of LPG Supply Sources.

LPG Supply-Source	Location	Production capacity (ton/month)
Rayong gas separation plant	The East of Thailand	80,000
Khanom gas separation plant	The South of Thailand	25,000
Thai Shell plant	The North of Thailand	9,000
Oil refinery	The east of Thailand	15,000
	Total	137,000

From Table 3.1., most of supply quantities (75% of all) come from the East of Thailand and the rest comes from the South and the North. PTT spreads these supply quantities to seven LPG depots located over the country for PTTs' customers and other major oil compan;e,s such as Shell, Esso, etc. it is called a supply sale. Then from the seven depots, PTT transports the products to their customers, and supply sale delivers their volume to their clients as well. Current LPG demands of seven depots are shown in table 3.2.

Table 3.2. LPG Demand of The Seven Depots in Year 2001.

PTTs' depots	Demand (ton/month)		
	PTTs' customers	Supply Sale	Total
Bangkok depot (BKK)	20,000		20,000
Banrongpo depot (BRP)	4,000	50	4,050
Khonkean depot (KKN)	8,900	7,600	16,500
Lump ang (LMP)	7,000	6,000	13,000
Nakornsawan (NSW)	5,600	5,100	10,700
Suratthani (STN)	4,500	3,500	8,000
Songkhla (SKL)	3,000	4,000	7,000
Total	53,000	26,250	79,250

Bangkok depot normally serves the Central region demand and Banrongpo is LPG depot for the East. Khonkean depot is only one LPG depot to serve the Northeast demand, Lumpang and Nakornsawan depots supply LPG for the North. Suratthani and Songkhla depots are LPG distribution centers for upside and downside of the South,

respectively. The total demand around 80,000 ton/month transferred to seven depots is domestic volume supplied from the four LPG plants which has 137,000 ton/month as their maximum production capacity, however, there are some over supply quantities which are exported to Indochina area.

3.2 LPG Physical Distribution Pattern and Cost

At present, PTT distributes LPG from the four sources to the seven depots by four transportation modes- pipeline, barge, truck and rail. Pipeline is used for carrying a big volume from Rayong plant to Banrongpo depot and from Banrongpo depot, a distribution center, and LPG is transferred to the North and the Northeast by rails and sometimes trucks. Although rail transportation cost is much cheaper than that of trucks, PTT usually utilizes truck fleet to carry LPG from Bangrongpo depot to Lumpang depot. This is because there is not enough train bogies to haul a whole volume of the North and the Northeast depots, today PTT utilizes ninety LPG bogies and almost fifty trailers. More than eighty percent of truck fleet is regularly used in Thai Shell plant to Lumpang depot route since there is no alternative mode to select. However, high transportation cost of truck does not hurt PTT since all transshipment costs are still compensated from the government. For barge, it is the cheapest transportation mode but only a few depots can receive product by ship. PTT barges LPG from Rayong plant to Bangkok depot, from Khanom to Suratthani and Songkhla depot, and also from Banrongpo, a distribution center, to Bangkok depot. Nowadays, PTT transfers more than 40,000 ton/month of LPG by pipeline to Banrongpo depot, around 35,000 ton/month by barge to Bangkok and the South depots, almost 30,000 ton/month by rail and less than 15,000 ton/month to the North and the Northeast depots by truck mode. And PTT has to pay a total of 30-35 million baht monthly for the current LPG transportation tl 'at could be separated into 15, 13, and 8 million baht for truck, railroad

and barge carrying mode, respectively. Table 3.3. summarizes LPG distribution volume and its transportation cost categorized by transportation mode at present and the current LPG physical distribution figure is depicted in Figure 3.1.

Table 3.3. LPG Distribution Volume and Transportation Cost at Present.

Mode	Truck	Railroad	Barge	Pipeline	Total
Volume (ton/month)	12,200	28,000	35,500	40,250	115,450
Cost (mmb/month)	15.4	12.8	7.5	0	35.7

3.3 LPG Depot Facilities

Each depot has different sphere tank capacities and number of truck loading bays that was designed to fit the demand of each area.

Table 3.4. Sphere Tank Capacities and Number of Truck Loading Bays Information.

Depot	Sphere tank capacity (ton)	Number of track loading bays
Bangkok (BKK)	3,000	6
Banrongpo depot (BRP)	3,000	2
Khonkean depot (KKN)	2,000	4
Lumpang (LMP)	2,000	4
Nakornsawan (NSW)	2,000	4
Suratthani (STN)	2,000	2
Songkhla (SKL)	2,000	2
Total	16,000	24

Most sphere tanks are constructed for at least 500 ton capacity per tank because of its economic cost. For all loading bays, their design maximum flow rates are about thirty-two ton per hour. Sphere tank capacities and number of truck loading bays at seven depots are shown in Table 3.4

Summary: l'oday, PTT distributes almost 80,000 ton of LPG monthly from four supply sources located in the East, the North and the south of Thailand to the seven LPG depots decentralized over the country by four transportation modes, pipeline, barge, truck and rail. The monthly total transportation cost is about 30-35 million baht. All transshipment costs are now compensated from the government because of the unique price policy, and this policy makes LPG have the same price at every depot. Then, LPG is distributed from the seven depots to customers in local area by trucks. Currently, PTT has 16,000 ton of LPG sphere tank capacity and 24 loading bays that have capability to discharge 768 ton of LPG per hour into truck to serve customers.

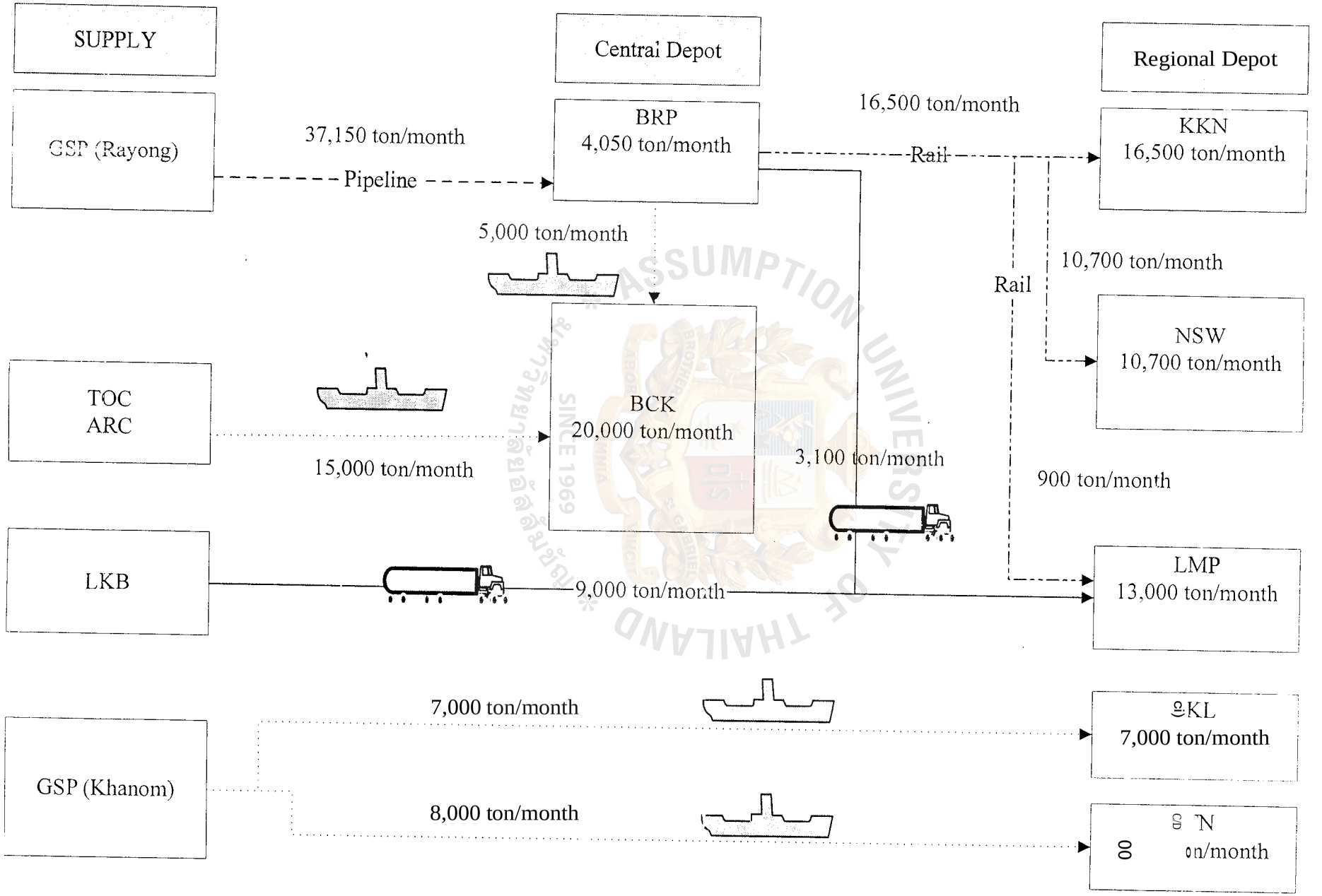

Figure 3.1. Current LPG Physical Distribution

IV, LPG LOGISTICS SYSTEM AFTER PRICE FLOATING

New LPG logistics system is created because of many factors. The major one is LPG floating price policy that would be announced in 2003 by the government. This policy causes LPG each depot demand change, affects transportation pattern and also depot facilities. This chapter describes LPG logistics in the future covering four topics that are supply sources, demand of all depots, physical distribution and depot facility requirement in 2002-2006.

4.1 **LPG Supply and Demand in 2002-2006**

In the previous chapter, there are now four LPG supply sources with 137,000 ton/month maximum production capacity. These supply groups still have capability to serve increased LPG domestic demand, but export volume would be reduced. If PTT wants to maintain or raises export volume, production capacity increase will be done. Table 4.1. shows LPG domestic demand compared with existing production capacity in year 2002-2006.

Table 4.1. Domestic demand, export volume and production capacity in 2002-2006.

Year	2002	2003	2004	2005	2006
Production capacity (ton/month)	137,000	137,000	137,000	137,000	137,000
Domestic demand (ton/month)	83,655	87,695	97,626	108,664	121,167
Export volume (ton/month)	53,345	49,305	39,374	28,336	15,833

From Table 4.1., LPG domestic demand grows 5%, 11%, 11% and 112% in 2003 to 2006. respectively, as growth percent is set up by sales and marketing department. This increased demand make Indochina export volume down from 53,345 ton/month in 2002 o 15,833 ton/month in 2006. PTT should concern whether to increase LPG production capacity or not by considering margins of export volume compared with expanded capacity investment. However, if LPG demand increases continuously, the existing production capacity can serve national demand as far as 2006. So PTT should prepare a plan to increase LPG production capacity in order to serve the domestic demand in the next 6 years.

After LPG price floating in 2003, customers especially some of supply sales who have their own fleet trucks will change LPG pick up point from the North and Northeast to Banrongpo depot in order to take low price advantage.

Table 4.2. LPG Demand of Seven Depots in 2002-2006.

Depot	Monthly average LPG demand in each year (ton/month)				
	2002	2003	2004	2005	2006
Bangkok	21,000	22,260	23,596	25,011	26,762
Banrongpo	4,253	8,455	13,174	18,458	25,548
Khonkean	17,490	16,990	18,350	19,818	21,403
Lumpang	13,520	12,763	13,273	13,804	14,357
Nakomsawan	11,342	10,054	10,858	11,726	12,665
Surattthani	8,560	9,159	9,800	10,584	11,431
Songkhla	7,490	8,014	8,575	9,261	10,002

Table 4.2. summarizes LPG demand of seven depot in 2002-2006. From the above Table, in 2003 (year of LPG price floating) demand of Banrongpo depot increases double, however, Khonkean, Lumpang and Nakornsawan demand drop about 15%. Price floating policy will not affect another depot demands because customers does not have other better pick-up point to be their alternatives. For example, southern customers should pick up LPG at Suratthani or Songkhla depot, and it is unreasonable for them to drive from the South in order to loading LPG at the East or Bangkok depot because of too long distance.

4.2 LPG Physical Distribution and Transportation Cost in 2002-2006

In 2003 PTT should purchase new 18 LPG train bogies to carry products from Banrongpo to Khonkean, Lumpang and Nakornsawan depots instead of truck fleet utilization. Because from the year 2003, the government will not pay compensation for transportation cost anymore, PTT shall find the optimized transportation routes and modes. These 18 train bogies investment will increase 65 baht/ton of rail transportation cost, however, it is still cheaper than truck mode. Apart from cheaper transportation cost, railroad is also safer than truck. For Bangkok and southern depots, barge transportation is still the most suitable mode compared to railroad and truck. LPG transportation separated by mode in year 2002-2006 demonstrates in Table 4.3. In 2002, new 18 train bogies have not purchased yet, the old 90 bogies can carry 28,000 ton/month of LPG. When more 18 bogies will be purchased in 2003, LPG carried by railroad increase to 32,500 ton/month at maximum capability while truck transportation slightly declines because of railroad distribution replacement. In 2002-2006, the majority volume, about 35-44% will be transferred by pipeline mode. Barge, railroad, and truck will transport another volume of about 30%, 20-25% and 8-12% respectively. Most of railroad transportation will be used in Khonkean and Lumpang route, more than

70% of truck fleet is utilized in Thai Shell — Nakornsawan or Lumpang route and the majority of barge volume is shipped from the refinery in the East of Thailand to Bangkok depot. PTT try to limit truck transportation by railroad replacement because it brings about public problems and quite hazardous mode.

Table 4.3. LPG Volume Separated by Transportation Mode in 2002-2006.

Mode	Monthly average LPG transportation volume (ton/month)				
	2002	2003	2004	2005	2006
Truck	14,352	9,000	9,981	12,848	15,925
Railroad	28,000	30,807	32,500	32,500	32,500
Barge	37,050	39,433	41,971	44,856	48,195
Pipeline	43,605	46,522	55,251	64,817	75,735
Total	123,007	125,762	139,703	155,021	172,355

Total LPG transportation cost continually increases in accordance with a demand, PTT will have to pay about 32.6 — 44.5 million baht/month for LPG transportation in 2002-2006. In 2002 PTT pay more transportation cost than in 2003 though its transportation volume is lower. This is because PTT has only 90 LPG train bogies in 2003, but 108 bogies in 2003, this makes PTT utilize more truck fleet with high freight in 2002 than in 2003. Table 4.4. shows that PTT disburses about 45-57% of transportation cost for rail mode, and the rest payment for barge and truck transportation. There are no pipeline carrying cost as pipeline belongs to PTT and it is used to transit LPG from Rayong plant to Banrongpo depot. In 2003, railroad transportation dramatically increases because new 18 train bogies will be purchased and

utilized instead of existing truck fleet. On the other hand, truck transportation drastically drops in 2003 because about 4,500 ton/month of LPG will be supplanted by a new train series.

Table 4.4. LPG Transportation Cost Separated by Transportation Mode in 2002-2006.

Mode	Monthly average LPG transportation cost (baht/month)				
	2002	2003	2004	2005	2006
Truck	11.3	4.5	5.6	9.1	13.7
Railroad	16.6	19.7	20.8	21.0	20.5
Barge	7.9	8.4	9.0	9.6	10.3
Pipeline	0	0		0	0
Total	35.8	32.6	35.4	39.7	44.5

4.3 Depot Facility Requirement in 2002-2006

Depot facilities PTT highly concerned are LPG storage tank and LPG truck (un)loading bay, LPG sphere tank requirement directly depends on throughput volume, depot with high demand would require more tank capacity than depot with low throughput. Beyond throughput, batch size of shipment affects LPG tank size as well. Table 4.5. shows over/(under) space requirement of LPG sphere tank of seven depots in 2002-2006 before improvement. Bangkok depot is in critical situation. It is risky to have a shortage because of too small tank capacity. Theoretically, Bangkok depot should have a new 500 tons of LPG storage tank in 2002 in order to serve increasing demand until 2006. However, PTT have not planned a new LPG tank construction because Bangkok depot tends to be moved out from the capital area within the next five years.

For another depots except Banrongpo, there is no urgent necessity to construct a new storage tank as PTT can lower safety stock level to prolong construction investment. At Banronpo depot, it is required more 500 ton of LPG storage tank in 2006. LPG storage tank must contain at least 500 tons, otherwise, its usefulness will not cover construction cost.

Table 4.5. Over/(Under) Space Requirement of LPG Tank in 2002-2006.

Depot	Space over / (under) requirement (ton)				
	2002	2003	2004	2005	2006
Bangkok	-19	-140	-269	-405	-573
Banrongpo	+755	+512	+240	-65	-416
Khonkean	+250	+270	+191	+107	+15
Lumpang	-50	+23	-26	-77	-130
Nakornsawan	+596	+670	+624	+573	+519
Surattthani	+162	+93	+19	-71	-169
Songkhla	+286	+225	+161	+81	-4

The second depot facility is truck (un)loading bay. Its utilization at each depot in 2002-2006 before improvement is shown in Table 4.6. It indicates that Banrongpo depot utilizes bay more than 100% or it requires additional bay until 2004. Besides new bay construction, operation duration change is another alternative. to solve this problem. For example, Banrongpo depot can adjust working hours from normal operation (8-hour daily) to two-shift operation in 2004 and 2005, and construct one new bay in 2006 instead of one, two and three bay construction investment in 2004, 2005 and 2006,

respectively. This solution can extend investment from 2004 to 2006 and also increase bay utilization. Another depots that their bay utilization reaches 80% but not over 100% should prepare a plan to increase daily working hours or adjust working hours from normal operation to shift operation after 2006.

Table 4.6. (Un)loading Bay Utilization of Seven Depots in 2002-2006.

Depot	No. of truck (un)loading bay / Truck (un)/loading bay utilization (%)				
	2002	2003	2004	2005	2006
Bangkok	53%	56%	59%	63%	67%
Banrongpo	72%	64%	106%	168%	236%
Khonkean	77%	64%	69%	79%	80%
Lumpang	51%	48%	50%	52%	54%
Nakomsawan	51%	38%	44%	54%	74%
Surattthani	64%	69%	74%	80%	86%
Songkhla	56%	60%	64%	70%	75%

V. LPG LOGISTICS ANALYSIS AFTER PRICE FLOATING

In the beginning of year 2003, it is possible that the government will announce LPG price floating policy. This policy will affect LPG demand of each depot, some customers prefer to receive their volumes from the East depot closed supply source than regional depots because of cheaper price. So, PTT studies these effects and find the optimum solutions of LPG logistics to cope with its price floating in 2003. The studies cover LPG demand forecasting in next five years, LPG physical distribution after price floating, LPG tank capacity and number of LPG loading bay requirement in year 2002-2006.

5.1 LPG Demand Forecasting in Year 2002-2006

Although there are many demand forecasting methods, sale department policy or sale force is the most accurate forecast for PTT. At the end of every year, LPG sale department has to set target or sales growth rate of the product separated by seven depots five years in advance. At this moment, LPG sales growth rates of all PTTs' depots in 2002-2006 are announced and their percentage growths are demonstrated in Table 5.1.

From the percentage of sales growth shown in Table 5.1 LPG demand of each depot in year 2002-2006 can be derived from

LPG demand in yr n+l = LPG demand in yr n x (l+percent of sales growth of yr n+1)

For example, if the average demand of Bangkok depot in year 2001 equals to 20,000 ton/month, its demand in year 2002 will be equal to;

20,000 x (1+5%) = 21,000 ton/month

Table 5.1. LPG Sales Growth of Seven Depots in Year 2002-2006.

Depot	Year				
	2002	2003	2004	2005	2006
Bangkok	5%	6%	6%	6%	7%
Banrongpo	5%	6%	6%	6%	7%
Khonkean	6%	7%	8%	8%	8%
Lumpang	4%	4%	4%	4%	4%
Nakornsawan	6%	7%	8%	8%	8%
Surattthani	7%	7%	7%	8%	8%
Songkhla	7%	7%	7%	8%	8%

However, LPG demand of each depot composes of two groups, demands of PTTs' customers or market demand and demands of others' customers or supply sale demand In the beginning of 2003, LPG price will be floated and this is anticipated that LPG demand of supply sale at Khonkean, Lumpang and Nakornsawan depots will dramatically drop about 30%. All of this missing demand will transfer to Banrongpo depot because supply sales who have their own truck fleets tend to pick up their volume from depot closed supply source because of the cheaper price. For the central and southern depots, this floating price policy does not affect supply sale demands because

these depots have been located near the supply source. So, the demand of the North and Northeast depot in year 2003 would be

Demand of the North and Northeast depot in 2003 =

[mkt demand in 2002 x (1+ % sales growth in 2003)]

+ [s/s demand in 2002 x (1+ % sales growth in 2003) x 70%)

And the 30% missing volume of supply sales from Khonkean, Lumpang and Nakornsawan depots will be added up to the demand of Banrongpo depot in year 2003 as well.

Table 5.2. shows the details of forecast LPG demand separate market and supply sales of seven depots in 2002-2006 in which the percentage growth is stipulated by LPG sales department. The result demonstrates that LPG volume of the northern and northeastern depots in 2003 do not increase while others do, on the contrary, demand of Banrongpo depot extremely increases in year 2003. For the remaining depots, their demands grow as usual.

Table 5.3 Forecasting Demand for LPG in 2002-2006.

	Year	2002	2003*	2004	2005	2006
BCK,	Growth rate		6%	6%	6%	7%
	MKT	21,000	22,260	23,596	25,011	26,762
	S/S	0	0	0	0	0
	total (ton/mth)	21,000	22,260	23,596	25,011	26,762
BRP	Growth rate	5%	6%	6%	6%	7%
	MKT	4,200	4,452	4,719	5,002	5,352
	S/S	53	4,003	8,455	13,456	19,196
	total (ton/mth)	4,253	8,455	13,174	18,458	24,548
KKN	Growth rate	6%	7%	8%	8%	8%
	MKT	9,434	10,094	10,902	11,774	12,716
	S/S	8,056	8,620	9,310	10,054	10,859
	S/S float	8,056	6,896	7,448	8,043	8,687
	total (ton/mth)	17,490	16,990	18,350	19,818	21,403
LMP	Growth rate	4%	4%	4%	4%	4%
	MKT	7,280	7,571	7,874	8,189	8,517
	.S/S	6,240	6,490	6,749	7,019	7,300
	S/S float	6,240	5,192	5,399	5,615	5,840
	total (ton/mth)	13,520	12,763	13,273	13,804	14,357
NSW	Growth rate	6%	7%	8%	8%	8%
	MKT	5,936	6,352	6,860	7,408	8,001
	S/S	5,406	4,628	4,998	5,398	5,829
	S/S float	5,406	3,702	3,998	4,318	4,663
	total (ton/mth)	11,342	10,054	10,858	11,726	12,665
STN	Growth rate	7%	7%	7%	8%	8%
	MKT	4,815	5,152	5,513	5,954	6,430
	S/S	3,745	4,007	4,288	4,631	5,001
	total (ton/mth)	8,560	9,159	9,800	10,584	11,431
SKL	Growth rate	7%	7%	7%	8%	8%
	MKT	3,210	3,435	3,675	3,969	4,287
	S/S	4,280	4,580	4,900	5,292	5,716
	total (ton/mth)	7,490	8,014	8,575	9,261	10,002

* LPG floating price in 2003

5.2 LPG Physical Distribution in Year 2002-2006

Since LPG price will be floated in year 2003, PTT will not receive transportation cost compensation from the government. Therefore, routes and modes to carry LPG from supply sources to seven depots will be major things to be concerned because they directly affect PTT's transportation cost.

LPG forecast demands of seven depots from previous description are used to run linear programming, and the program solution points out the most suitable routes and modes for each LPG ton from origins to destinations. Some depots are fixed by only one mode, for example, Bangkok, Suratthani and Songkhla depots can receive LPG only by barge mode, Bangrongpo can receive the product only by pipeline. LPG demand of these constraint depots are not necessary to run linear programming to find the most suitable mode since there is only one mode to reach them. However, LPG volumes of the North and Northeast depots (Khonkean, Lumpang and Nakornsawan depots) shall ask for linear programming, as there is more than one LPG carrying modes to approach them.

There are two LPG transportation modes, which are truck and rail, and two possible origins-Banrongpo depot and Thai Shell- can reach to the northern and northeastern depots. Today, PTT has ninety bogies of train that can carry LPG about 28,000 ton monthly, in the event that PTT requires to transfer more than 28,000 ton/month by rail, and the number of LPG bogies increase is necessary. The linear program running shows two solutions of the northern and northeastern LPG physical distribution in each year from 2002 until 2006. The first case is run based on current number of rail bogies (ninety bogies) and the second based on one train series (eighteen bogies) will rise in 2003.

The first case, no rail bogies increment, the linear program firstly selects demands of Khonkean and Lumpang depot to be transferred by railroad from Banrongpo depot, the cheapest route, after that Nakomsawan demand is selected if there is enough rail transportation capacity. The rest volume of Nakomsawan depot is then carried by truck from Thai Shell very close to Nakornsawan, and the left supply volume of Thai Shell will be sent to Lumpang depot. Finally, volume of all depots cannot be delivered by rail from Banrongpo and by truck from Thai Shell, so the remaining volume is carried by truck from Banrongpo depot, which is the most expensive route.

The second case, eighteen bogies raise in 2003, all 108 bogies (90 old and 18 new bogies) can carry 32,500 ton of LPG monthly, 4,500 ton increased. PTT has to invest about 170 million baht for this new rail series and this shall increase 65 baht/ton to rail transportation cost; however, transportation cost of rail mode is still much cheaper than truck mode. So it is reasonable for PTT to increase one series of train in year 2003. For the second case, the program starts to select rail mode to serve Khonkean, Lumpang and some of Nakornsawan demands, but more volume than the first case can be moved by rail mode because of 18 bogies. And the rest of Nakomsawan demand is firstly supplied from Thai Shell and the last is carried from Banrongpo by truck. Even though, PTT invests almost 200 million baht to buy a new train series, total transportation cost including investment is cheaper than increased truck fleet with high freight.

Investment of new 18 bogies, 171 million baht, can be converted into transportation cost following these steps;

(a) Calculating annually payment of 171 million baht in 15 years by use Excel function;

Annually payment = PMT(0.08,15,171,25,0) = 20.9 mmb/yr

@ interest rate=8%, 15 years train utilization, 171 million baht investment, 25 million baht for salvage value and payment is paid at the end of year

(b) Converting annually payment to transportation cost by;

21 mmb/yr = 20 / (4,_;00*12) = 387 baht/ton @18 bogies can carry LPG 4,500 ton/month

(c) Calculating new rail freight;

New rail transportation cost equal to (387*18) / (90+18) = 64 baht/ton

@ weighted average cost to all bogies, 90 old bogies and 18 new bogies

Table 5.3.-5.11. show results of linear programming to find the optimum solution of LPG transportation route in 2002-2006 in two cases, no rail bogies increment and 18 bogies increase in 2003.

Table 5.3. LPG Physical Distribution and Total Cost in 2002 in Case of 90 Bogies.

	Source	Pipeline	Barge			Rail	Truck		Total
Destination		Ravong	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	14,480	0	3,010	17.490
	baht/ton	9.999	9,999	9,999	9,999	500	2,000	1,400	
	baht	0	0	0	0	7,240.000	0	4,214,00	11,454.000
LMP	ton/month	0	0	0	0	13,520	0	0	13.520
	bahtlton	9,999	9,999	9,999	9,999	690	1,000	2,000	
	baht	0	0	0	0	9,328.800	0	0	9,328.800
NSW	ton/month	0	0	0	0	0	9,000	2,342	11.342
	baht/ton	9399	9.999	9,999	9,999	370	500	1,100	
	baht	0	0	0	0	0	4,500,000	2,576,20	7.076.200
BRP	ton/month	43.605	0	0	0	0	0	0	43.605
	bahtlton	0	9,999	9,999	9,999	9,999	9,999	9,999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15.000	6,000	0	0	0	0	21.000
	baht/ton	9.999	200	200	9,999	9,999	9,999	9,999	
	baht	0	3,000,000	1,200,000	0	0	0	0	4,200.000
STN	ton/month	0	0	0	8,560	0	0	0	8.560
	baht/ton	9 999	9,999	9,999	200	9,999	9,959	9,999	
	baht	0	0	0	1,712,000	0	0	0	1,712,000
SKL	ton/month	0	0	0	7,490	0	0	0	7.490
	baht/ton	9.999	9,999	9,999	270	9,999	9,999	9,999	
	baht	0	0	0	2,022,300	0	0	0	2.022.300
Total by mode	ton/month	43.605	15,000	6,000	16,050	28,000	9,000	5,352	123.007
								Cost (baht)	35,793.300
								Baht/ton	291

Table 5.4. LPG Physical Distribution and Total Cost in 2003 in Case of 90 Bogies.

Destination	Source	Pipeline	Barge			Rail	Truck		Total
		Rayong	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	15,237	0	1.753	16,990
	baht/ton	9,999	9.999	9,999	9,999	500	2,000	1,400	
	baht	0	C		0	7,618,500	0	2,454,200	10,072,700
LMP	ton/month	0	0	0	0	12.763	0	0	12,763
	baht/ton	9,999	9,999	9,999	9,999	690	1,000	2,000	
	baht	0	0		0	8,806,470	0	0	8,806,470
NSW	ton/month	0	0	0	0	0	9,000	1,054	10,054
	baht/ton	9,999	9,999	9.999	9,999	370	500	1,100	
	baht	0	0	0	0	0	4,500,000	1,159,400	5,659,400
BRP	ton/month	46,522	0	0	0	0	0	0	46,522
	baht/ton	0	9,999	9,999	9,999	9,999	9,999	9,999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15,000	7,260	0	0	0	0	22,260
	baht/ton	9,999	200	200	9,999	9,999	9,999	9,999	
	baht	0	3,000,000	1,452,000	0	0	0	0	4,452,000
STN	ton/month	0	0	0	9,159	0	0	0	9,159
	baht/ton	9,999	9,999	9,999	200	9,999	9,999	9,999	
	baht	0	0	0	1,831,800	0	0	0	1,831,800
SKL	ton/month	0	0	0	8,014	0	0	0	8,014
	baht/ton	9,999	9.999	9,999	270	9,99[9]	9,999	9,999	
	baht	0	0		2,163,780	0	0	0	2,163,780
Total by mode	ton/month	46,522	15,000	7,260	17,173	28,000	9,000	2,807	125,762
								Cost (baht)	32,986,150
								Baht/ton	262

Table 5.5. LPG Physical Distribution and Total Cost in 2003 in Case of 108 Bogies.

Destination	Source	Pipeline	Barge			Rail*	Truck		Total
		Rayoog	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	16.990	0	0	16,990
	baht/ton	,999	9,999	9,999	9,999	565	2,000	1,400	
	baht	' 0	0		01	9599,350	0	0	9,599,350
1.1\41'	ton/month	0	0	0	0	12,763	0	0	12,763
	baht/ton	9,999	9,999	9.999	9,999	755	1,000	2,000	
	baht	0	0	0	0	9.636,065	0	0	9,636,065
NSW	ton/month	0	0	0	0	1,054	9,000	0	10,054
	baht/ton	9,999	9,999	9.999	9,999	435	500	1,100	
	baht	0	0	0	0	458,490	4,500,000	0	4.958,490
BRP	ton/month	46.522	0	0	0	0	0	0	46,522
	baht/ton	0	9,999	9.999	9,999	9,999	9,999	9,999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15,000	7.260	0	0	0	0	22,260
	baht/ton	9,999	200	200	9,999	9,999	9,999	9,999	
	baht	0	3,000,000	1,452,000	0	0	0	0	4,452,000
STN	ton/month	0	0	0	9,1591	0	0	0	9,159
	baht/ton	9,999	9,999	9.999	200	9,999	9,999	9,999	
	baht	0	0	0	1,831,800	0	0	0	1,831800
SKL	ton/month	0	0	0	8,014	0	0	0	8.014
	baht/ton	9,999	9,999	9.999	270	9,999	9,999	9,999	
	baht	0	0	0	2,163.780	0	0	0	2,163,780
Total by mode	ton/month	46,522	15,000	7 760	17,173	30,807	9,000	0	125,762
								Cost (baht)	32,641,485
								Baht/ton	260

* Rail transportation cost increases 65 baht/ton because of 18 new bogies purchasing

Table 5.6. LPG Physical Distribution and Total Cost in 2004 in Case of 90 Bogies.

	Source	Pipelnw.	Barge			Rail	Tr ick		Total
Destination		Rayong	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	14,727	0	3,623	18,350
	baht/ton	9,999	9,999	9,999	9,999	500	2.000	1,400	
	baht	0	0		0	7,363,500	0	5,072,200	12,435,700
LMP	ton/month	0	0	0	0	13,273	0	0	13,273
	baht/ton	9,999	9,999	9,999	9,999	690	1.000	2,000	
	baht	0	0		0	9,158,370	0	0	9,158,370
NSW	ton/month	0	0	0	0	0	9.000	1,858	10,858
	baht/ton	9,999	9,999	9,999	9,999	370	500	1,100	
	baht	0	0	0	0	0	4,500.000	2,043,800	6,543,800
BRP	ton/month	55.251	0	0	0	0	0	0	55,251
	baht/ton	0	9,999	9,999	9,999	9,999	9.999	9,999	
	baht	0	0	0	0	0	0	0	
BCK	ton/month	0	15,000	8,596	0	0	0	0	23,596
	baht/ton	9,999	200	200	9,999	9,999	9.999	9,999	
	baht	0	3,000,000	1,719,200	0	0	0	0	4,719,200
STN	ton/month	0	0	0	9,800	0	0	0	9,800
	baht/ton	9,999	9,999	9,999	200	9,999	9,999	9,999	
	baht	0	0	0	1,960,000	0	0	0	1,960,000
SKI,	ton/month	0	0	0	8,575	0	0	0	8,575
	baht/Lon	9,999	9,999	9,999	270	9,999	9,999	9,999	
	baht	0	0	0	2,315,250	0	0	0	2,315,250
Total by mode	ton/month	55,251	15,000	8,596	18,375	28,000	9,000	5,481	139,703
								Cost (baht)	37,132,320
								Baht/ton	266

Table 5.7. LPG Physical Distribution and Total Cost in 2004 in Case of 108 Bogies.

Destination	Source	Pipeline	Bartle			Rail*	Truck		Total
		Ravone	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	18,350	0	0	18,350
	baht/ton	9,999	9,999	9,999	9,999	565	2,000	1,400	
	baht	0	0		0	10,367,750	0	0	10,367,750
LMP	ton/month	0	0	0	0	13,273	0	0	13,273
	baht/ton	9.999	9,999	9.999	9,999	755	1,000	2,000	
	baht	0	0	0	0	10,021,115	0	0	10,021,115
NSW	ton/month	0	0	0	0	877	9,000	981	10,858
	baht/ton	9,999	9,999	9.999	9,999	435	500	1,100	
	baht	0	0	0	0	381,495	4,500,000	1,079,100	5,960,595
BRP	ton/month	55,251	0	0	0	0	0	0	55,251
	baht/ton	0	9,999	9.999	9,999	9,999	9,999	9,999	
	baht	0	0	0	0	0	C	0	0
BCK	ton/month	0	15,000	8.596	0	0	0	0	23.5%
	baht/ton	9,999	200	200	9,999	9,999	9,999	9,999	
	baht	0	3,000,000	1,719,200	0	0	0	0	4,719,200
STN	ton/month	0	0	0	9,800	0	0	0	9,800
	baht/ton	9,999	9,999	9,999	200	9,999	9,999	9,999	
	baht	0	0	0	1,960,000	0	0	0	1,960,000
SKL	ton/month	0	0	0	8,575	0	0	0	8,575
	baht/ton	9,999	9,999	9,999	270	9,999	9,999	9,999	
	baht	0	0	0	2,315,250	0	0	0	2,315,250
Total by mode	ton/month	55,251	15,000	8,596	18,375	32,500	9,000	981	139,703
								Cost (baht)	35,343,910
								Baht/ton	253

* Rail transportation cost increases 65 baht/ton because of 18 new bogies purchasing

Table 5.8. LPG Physical Distribution and Total Cost in 2005 in Case of 90 Bogies.

Destination	Scurce	Pipeline	Barge			Rail	Truck		Total
		Rayone,	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	14.196	0	5,622	19.818
	baht/ton	9,999	9,999	9.999	9,999	500	2,000	1.400	
	baht	0	0		0	7.098.000	0	7,870,800	14,968,800
LMP	ton/month	0	0	0	0	13.804	0	0	13,804
	baht/ton	9.999	9,999	9.999	9.995	690	1,000	2,000	
	baht	0	0	0	0	9.524.760	0	0	9,524,760
NSW	ton/month	0	0	0	0	0	9,000	2.726	11,726
	baht/ton	9,999	9,999	9.999	9,999	370	500	1,100	
	baht	0	0	0	0	0	4,500,000	2,998,600	7,498,600
BRP	ton/month	64,817	0	0	0	0	0	0	64,817
	baht/ton	0	9,999	9.999	9,999	9.999	9,999	9,999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15,000	10.011	0	0	0	0	25,011
	baht/ton	9,999	200	200	9,999	9.999	9,999	9,999	
	baht	0	3,000,000	2,002,200	0	0	0	0	5,002,200
STN	ton/month	0	0	0	10,584	0	0	0	10,584
	baht/ton	9,999	9,999	9.999	200	9.999	9,999	9,999	
	baht	0	0	0	2,116,800	0	0	0	2,116,800
SKL	ton/month	0	0	0	9,261	0	0	0	9,261
	baht/ton	9,999	9,999	9.999	270	9.999	9,999	9,999	
	baht	0	0	0	2,500,470	0	0	0	2,500,470
Total by mode	ton/month	64,817	15,000	10,011	19,845	28.000	9,000	8,348	155,021
								Cost (baht)	41,611,630
								Baht/ton	268

Table 5.9. LPG Physical Distribution and Total Cost in 2005 in Case of 108 Bogies.

Destination	Source	Pipeline	Barge			Rail*	Truck		Total
		Rayong	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	18,696	0	1,122	19,818
	baht/ton	9,999	9.999	9,999	9,999	565	2,000	1,400	
	baht	0	0		0	10,563,240		,570,800	12,134,040
LMP	ton/month	0	0	0	0	13,804	0	0	13,804
	baht/ton	9,999	9,999	9,999	9.999	755	1,000	2,000	
	baht	0	0	0	0	10,422,020	0	0	10,422,020
NSW	ton/month	0	0	0	0	0	9.000	2,726	11,726
	baht/ton	9,999	9.999	9,999	9.999	435	500	1,100	
	baht	0	0	0	0	0	4,500,000	2,998,600	7,498,600
BRP	ton/month	64,817	0	0	0	0	0	0	64,817
	baht/ton	0	9,999	9,999	9,999	9,999	9.999	9,999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15,000	10,011	0	0	0	0	25,011
	baht/ton	9,999	200	200	9,999	9,999	9.999	9,999	
	baht	0	3,000,000	2,002,200	0	0	0	O	5,002,200
STN	ton/month	0	0	0	10,584	0	0	0	10,584
	baht/ton	9,999	9,999	9,999	200	9,999	9,999	9,999	
	baht	0	0	0	2,1 i 6,800	0	0	0	2, 116, 80(1
SKL	ton/month	0	0	0	9,261	0	0	0	9,261
	baht/ton	9,999	9,999	9,999	270	9,999	9,999	9,999	
	baht	0	0	C	2,500,470	0	0	0	2,500,470
Total by mode	ton/month	64,817	15,000	10,011	19,845	32,500	9,000	3,848	155,021
								Cost (baht)	39,674,130
								Baht/ton	256

* Rail transportation cost increases 65 baht/ton because of 18 new bogies purchasing

Table 5.10. LPG Physical Distribution and Total Cost in 2006 in Case of 90 Bogies.

	Source	Pipeline	Barge			Rail	Truck		Total
Destination		Rayong	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	13,643	0	7,760	21,403
	baht/ton	9,999	9,999	9,999	9,999	500	2,000	1,400	
	baht	0	0	0	0	6,821,500	0	10,864,000	17,685,500
L MP	ton/month	0	0	0	0	14,357	0	0	14,357
	baht/ton	9,999	9,999	9,999	9,999	690	1,000	2,000	
	baht	0	0	0	0	9,906,330	0	0	9,906,330
NSW	ton/month	0	0	0	0	0	9,000	3,665	12,665
	baht/ton	9,999	9,999	9,999	9,999	370	500	1,100	
	baht	0	0	0	0	0	4,500,000	4,031,500	8,531,500
BRP	ton/month	75,735	0	0	0	0	0	0	75,735
	baht/ton	0	9,999	9,999	9,999	9,999	9,999	9,999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15,000	11,762	0	0	0	0	26,762
	baht/ton	9,999	200	200	9,999	9,999	9,999	9,999	
	baht	0	3,000,000	2,352,400	0	0	0	0	5,352,400
STN	ton/month	0	0	0	11,431	0	0	0	P1,431
	baht/ton	9,999	9,999	9,999	200	9,999	9,999	9,999	
	baht	0	0	0	2,286,200	0	0	0	2,286,200
SKL	ton/month	0	0	0	10,002	0	0	0	10,002
	baht/ton	9,999	9,999	9,999	270	9,999	9,999	9,999	
	baht	0	0	0	2,700,540	0	0	0	2,700,540
Total by mode	ton/month	75,735	15,000	11,762	21,433	28,000	9,000	11,425	172,355
								Cost (baht)	46,462,470
								Baht/ton	270

Table 5.11. LPG Physical Distribution and Total Cost in 2006 in Case of 108 Bogies.

Destination	Source	Pipeline	Barge			Rail*	Truck		Total
		Rayong	Refinery	BRP	Khanom	BRP	LKB	BRP	
KKN	ton/month	0	0	0	0	21.403	0	0	21,403
	baht/ton	9.999	9,999	9,999	9,999	565	2,000	1,400	
	baht	0	0	0	0	12.092.695	0	0	12,092,695
LMP	ton/month	0	0	0	0	11.097	3.260	0	14,357
	baht/ton	9.999	9,999	9,999	9,999	755	1,000	2.000	
	baht	0	0	0	0	8.378.235	3,260.000	0	11,638.235
NSW	ton/month	0	0	0	0	0	5,740	6.925	12,665
	baht/ton	9.999	9,999	9,999	9,999	435	500	1,100	
	baht	0	0	0	0	0	2,870,000	7.617,500	10,487,500
BRP	ton/month	75.735	0	0	0	0	0	0	75.735
	baht/ton	0	9,999	9.999	9,999	9,999	9.999	9.999	
	baht	0	0	0	0	0	0	0	0
BCK	ton/month	0	15,000	11,762	0	0	0	0	26,762
	baht/ton	9,999	200	200	9,999	9,999	9,999	9,999	
	baht	0	3,000,000	2,352,400	0	0	0	0	5,352,400
STN	ton/month	0	0	0	11,431	0	0	0	11,431
	baht/ton	9.999	9,999	9,999	200	9,999	9,999	9,999	
	baht	0	0	0	2,286,200	0	0	0	2,286,200
SKL	ton/month	0	0	0	10,002	0	0	0	10,002
	baht/ton	9,999	9,999	9.999	270	9,999	9,999	9,999	
	baht	0	0	0	2.700,540	0	0	0	2,700,540
Total by mode	ton/month	75,735	15,000	11,762	21,433	32,500	9,000	6,925	172355
								Cost (baht)	44,557,570
								Baht/ton	259

* Rail transportation cost increases 65 baht/ton because of 18 new bogies purchasing

5.3 LPG Sphere Requirement for Each Depot in Year 2002-2006

After forecasting LPG demand of each depot, PTT plans to provide necessary sphere or tank capacity suit. If LPG tank capacity are not enough or under requirement, PTT sh ill plan to construct a new sphere matching the future demand.

Typically, tank capacity sufficiency analysis follows three steps.

5.3.1 Effective Stock Calculation

LPG inventory that suffices both expected demand during normal lead time and unusual demand during emergency period called safety stock. Safety stock is not spent in normal operation, but in critical event such as natural disaster safety stock will be used.

Effective Stock = Expect demand during lead time + Safety stock

Lead time for each depot is different depending on the mode to transport and distance from supply source to the depot. Barge transportation takes longer time than truck and rail, on land transportation (truck and railroad) from Banrongpo to northern and northeastern depots takes about 2-3 days, and water carrier from eastern supply sources to southern depots takes 4-5 days and to Bangkok takes 2 days. And safety stock is often less than expected demand during lead time because transportation from the closet source must occur in critical events, and the optimization route is not concerned. Table 5.12. shows lead time and number of safety stock days for each depot.

Table 5.12. Lead Time and Number of Safety Stock Days for Seven Depots.

Depot	Lead time Normal supply	(Day)	Safety Stock Other closet supply source	(Day)
Bangkok	Barge from refinery	1.5	Truck from Banrongpo	1
Banrongpo	Pipeline from Rayong plant	0.5	Barge from refinery	1
Khonkean	Rail from Banrongpo	1	Truck from Banrongpo	0.5
Lumpang	Rail from Banrongpo	2	Truck from Nakornsawan	0.5
Nakornsawan	Truck from Thai Shell	1	Truck from Lumpang	0.5
Surattthani	Barge from Hkanom	2	Truck from Songkhla	1
Songkhla	Barge from Hkanom	2	Truck from Suratthani	1

5.3.2 tillage or Space for Batch Size

Tank space is provided to unload LPG in the next batch size. Ullage for each depot is varied depending on maximum volume depot which has ever received in one shipment. Generally, batch size of barge is greater than truck and rail, so sphere tank at southern depots will have enough space to receive a big volume, of about 550 ton per shipment. LPG batch sizes for seven depots are demonstrated in Table 5.13.

Table 5.13. LPG Batch Size of Each Depot.

Depot	Maximum batch size (ton)	Remark
Bangkok	550	Barge
Banrongpo	700	Pipeline
Khonkean	450	Rail
Lumpang	450	Rail
Nakornsawan	450	Rail
Surattthani	550	Barge
Songkhla	550	Barge

5.3.3 Tank Adequacy Analysis

After effective stock and batch size is estimated, tank sufficiency analysis is calculated by

Space over/(under) requirement = 85% of tank capacity - Effective stock - Batch size

The above equation shows that sphere tank can contain maximum LPG at 85% of its capacity because of safety regulation. The positive result from this equation means that LPG tank is still enough for demand in that period, vice versa, LPG tank capacity is necessary to increase. Table 5.14. shows LPG tank requirement analysis of all depots in 2002-2006.

Table 5.14. LPG Tank Requirement Analysis for Seven Depots in 2002-2006.

unit ton

	Year	2302	2003	2004	2005	2006
BKK	tank cap.	3,000	3,000	3,000	3,000	3,000
	85% of tank cap	2.550	2,550	2,550	2,550	2.550
	Expected demand during LT 1.5 day	1.212	1,284	1,361	1,443	1,544
	Safety stock 1 day	808	856	908	962	1,029
	Ullage	550	550	550	550	550
	Space over / (under) requirement	*-19.23*	*-140.38*	*-268.81*	*-404.94*	*-573.28*
BRP	tank cap.	2,000	2,000	2,000	2_000	2,000
	85% of tank cap	1.700	1,700	1,700	1,700	1,700
	Expected demand during LT 0.5 day	82	163	253	355	472
	Safety stock I day	164	325	507	710	944
	Ullage	700	700	700	700	700
	Space over / (under) requirement	754.66	512.21	239.98	*-64.90*	*-416.23*
KKN	tank cap.	2.000	2,000	2,000	2.000	2,000
	85% of tank cap	1,700	1,700	1,700	1.700	1,700
	Expected demand during LT 1 day	673	653	706	762	823
	Safety stock 0.5 day	336	327	353	381	412
	Ullage	450	450	450	450	450
	Space over / (under) requirement	240.96	269.79	191.37	106.68	15.22
LMP	tank cap.	2,030	2,000	2,000	2,000	2,000
	85% of tank cap	1,700	1,700	1,700	1,700	1,700
	Expected demand durii.. LT 2 day	1,040	982.	1,021	1,062	1,104
	Safety stock 0.5 day	260	245	255	265	276
	Ullage	450	450	450	450	450
	Space over / (under) requirement	-50.00	22.80	*-26.29*	*-77.34*	*-130.43*
NSW	tank cap.	2,000	2,000	2,000	2,000	2,000
	85% of tank cap	1,700	1,700	1,700	1,700	1,700
	Expected demand during LT 1 day	436	387	418	451	487
	Safety stock 0.5 day	218	193	209	226	244
	Ullage	450	450	450	450	450
	Space over / (under) requirement	595.65	669.99	623.59	573.47	519.35
STN	tank cap.	2,000	2,000	2,000	2,000	2,000
	85% of tank cap	1,700	1,700	1,700	1,700	1,700
	Expected demand during LT 2 day	658	705	754	814	879
	Safety stock 1 day	329	352	377	407	440
	Ullage	550	550	550	550	550
	Space over / (under) requirement	162.31	93.17	19.19	*-71.27*	*-168.98*
SKL	tank cap.	2,000	2,000	2,000	2,000	2,000
	85% of tank cap	1,700	1,700	1,700	1,700	1,700
	Expected demand during LT 2 days	576	616	660	712	769
	Safety stock 1 day	288	308	330	356	385
	Ullage	550	550	550	550	550
	Space over / (under) requirement	285.77	225.27	160.54	81.39	*-4.10*

5.4 Loading and Unloading Bay Requirement for Each Depot in 2002-2006

Loading bay is location trailer going inside in order to load LPG in bulk, but sometimes it is called unloading bay if the trailer goes inside for unloading LPG. The number of (un)loading bays should fit LPG demand; otherwise, transportation system inside depots will be jammed and LPG cannot be delivered to customers in time because of few (un)loading bay quantities. Most depots use only loading bay to load LPG into truck and deliver it to end customers, unloading bay is especially used in depot to receive LPG by truck in Nakornsawan and Lumpang depots.

$$\text{No. of bay} = \frac{\text{Daily ton of LPG unload by truck} + \text{Daily ton of LPG load by truck}}{\text{(32 ton per hour x 8 hour per day)}}$$

The above equation based on one (un)loading day can load or unload 32 tons of LPG per hour and PTT's work hour is 8 hours a day. However, PTT has to monitor (un)loading bay utilization so as to observe (un)loading bay sufficiency.

$$\text{\% (un)loading bay utilization} = \frac{\text{Daily ton of LPG load by truck} + \text{Daily ton of LPG unload by truck x 100 \%}}{\text{No of bay depot has x (32 ton per hour x 8 hour per day)}}$$

PTT should prepare a plan for depots where (un)loading utilization for each depot is greater than 80%. Table 5.15. shows the percentage of (un)loading bay for seven depots in 2002-2006.

Table 5.15. (Un)loading Bay Utilization of Seven Depots in 2001-2006.

	Year	2002	2003	2004	2005	2006
BCK	no. of bay	6	6	6	6	6
	(un)loading capacity (ton/day)	1,536	1,536	1,536	1,536	1,536
	thruput (ton/day)	808	856	908	962	1,029
	% bay utilization	53%	56%	59%	63%	67%
BRP	no. of bay	2	2	2	2	2
	(un)loading capacity (ton/day)	512	512	512	512	512
	thruput (tort/day)	369	325	544	858	1.210
	% bay utilization	72%	64%	*106%*	*168%*	*236%*
KKN	no. of bay	4	4	4	4	4
	(un)loading capacity (ton/day)	1,024	1,024	1,024	1,024	1,024
	thruput (ton/day)	788	653	706	805	823
	% bay utilization	77%	64%	69%	79%	80%
LMP	no. of bay	4	4	4	4	' 4
	(un)loading capacity (ton/day)	1,024	1,024	1,024	1,024	1,024
	thruput (ton/day)	520	491	511	531	552
	% bay utilization	51%	48%	50%	52%	54%
NSW	no. of bay	4	4	4	4	4
	(un)loading capacity (ton/day)	1,024	1,024	1,024	1,024	1,024
	thruput (ton/day)	526	387	455	556	753
	% bay utilization	51%	38%	44%	54%	74%
STN	no. of bay	2	2	2	2	2
	(un)ioading capacity (ton/day)	512	512	512	512	512
	thruput (ton/day)	329	352	377	407	440
	% bay utilization	64%	69%	74%	80%	86%
SKL	no. of bay	2	2	2	2	2
	(un)loading capacity (ton/day)	512	512	512	512	512
	thruput (ton/day)	288	308	330	356	385
	% bay utilization	56%	60%	64%	70%	75%

*(un)loading capacity 32 ton/hr

working hours 8 hr/day

VI. CONCLUSION AND RECOMMENDATION

7.1 Conclusion

Petroleum Authority of Thailand (PTT), a national energy organization has a major mission to serve Thai people and industriLs with various petroleum products. One of them is Liquid Petroleum Gas called LPG. PTT has a duty to transfer LPG from four supply sources with 137,000 tons per month maximum production capacity to seven LPG depots and the current domestic demand is about 80,000 ton per month. PIT balances supply and demand by exporting extra supply to Indochina area. Four transportation modes -pipeline, barge, rail and truck- are used to transfer the average 40,000, 32,500, 28,000 and 12,000 tons of LPG monthly and its total transportation cost is around 35 million baht/month. Barge is used for carrying LPG from supply sources to southern and Bangkok depots, fail mode around 28,000 ton/month is used for northern and.. northeastern depots. The rest volume of transportation is supported by truck mode. However, today the government compensates ail distribution cost for PTT as the government sets policy to fix LPG price of every depot uniquely.

In the next 2 years, in 2003, government will abolish the unique LPG price and announce a floating price policy. This event will change customers' behaviors especially some supply sales who have their own truck fleets will consider its product cost. They attempt to receive the products from depots with the lowest price while they will think of distance or transportation cost they have to pay as well. About 30% of supply sales will move to their received volume especially from the North and Northeast of country to the East, Banrongpo depots. The floating price policy and supply sales' behaviors alteration make demands of each depot change. PTT will

prepare a new transportation system with the lowest cost and depot facilities to serve changeable demands as well.

In the first step, forecasting LPG demand has been done by using sale forced method and it simultaneously applies 30% of supply sales volume at the North and Northeast depots decrement. The missing 30% volume will emerge at Banrongpo depot. Then, transportation pattern will be adjusted with the floating price policy and the increasing demand by low cost concern. So, PTT should increase a train series (18 bogies) to carry more 4,500 ton/month from the East to northern and northeastern depots instead of trucks. This can save 0.4 — 1.9 Million baht/month from railroad transportation increment and truck transportation decrement in 2003-2006. Table 6.1. shows LPG transportation costs in 2002-2006 in two cases. The first one is to maintain current vehicle fleets (no LPG train series purchasing) and the second is vehicle fleet improvement by 18 train bogies purchased in 2003.

Table 6.1. Total LPG Transportation Cost in Two Different Cases.

Depot	Monthly average transportation cost (million/month)				
	2002*	2003	2004	2005	2006
90 old & 18 new bogies (Fleet improvement)	35.8	32.6	35.3	39.7	44.6
90 old bogies (Current vehicle)	35.8	33.0	37.1	41.6	46.5
Different expense	0.0	0.4	1.8	1.9	1.9

*In 2002, there is no new 18 LPG train bogies

Finally, depot facility sufficiency will be analyzed. From theoretical LPG storage tank calculation, LPG storage tanks and truck loading bay are required to partly improve the system. For example, Banrongpo depot, require additional 500 ton of sphere tank in 2006 to avoid shortage situation. Besides tank storage, loading bays of Banrongpo should be increased in 2006, however, until 2004 two shifts operation will be necessary; otherwise, one additional bay needs to be constructed in 2004. After adjusting operation time in 2004 and constructing a new bay in 2006, new truck (un)loading bay utilization of Banrongpo depot is shown in Table 6.2.

Table 6.2. (Un)loading Bay Utilization of Banrongpo Before and After Improvement

	Year	2002	2003	2004	2005	2006
Before	No of bay	2	2	2	2	2
	Working hours	8	8	8	8	8
	% utilization	72%	64%	106%	168%	236%
After	No of bay	2	2	2	2	3
	Working hours	8	8	16	16	16
	% utilization	72%	64%	53%	84%	79%

7.2 Recommendation

LPG price floating in 2003 which combines normal demand increase directly affects many PTT's logistics parts. Some examples of them are demand change of each depot, physical distribution alteration, and also depot facility improvement.

Usually the domestic demand increases from about 80,000 ton/month in 2001 to almost 125,000 ton/month in 2006 while maximum production capacity of four supply

sources is consistent at 137,000 ton/month. The raised demand drops over supply to be exported decline continuously from about 60,000 ton/month in 2001 to about 10,000 ton/month. This situation makes PTT to decide whether production capacity should raise or constantly stand the capacity and reduce export volume. In this case, PTT should focus on the export price direction together with its demand. If both price and demand volume tend to increase, production capacity raise ought to be invested.

Both of LPG price floating in 2003 and increasing demand press PTT to consider own LPG transportation system. The price floating policy makes PTT price different in each depot because government will cancel PTT's freight compensation. From 2003 through 2006, PTT should increase railroad carriage by purchasing 18 LPG train bogies while reduce truck mode in order to obtain lower transportation cost. However, one train series increase may be not enough or match with the demand in the next 6 years because LPG demand grows quite rapidly. Provided that the demands of the North and Northeast depot dramatically increase, the next LPG train series should be considered to be invested because of its lower freight than truck mode.

Besides LPG physical distribution, depot facilities are an important part to be considered. PTT is recommended to focus on LPG storage tank, one of depot facilities, at Banrongpo and Bangkok depots because their tanks seem insufficiently following theoretical calculation and could be a cause of shortage situation. PTT can solve Banrongpo's problem by building a new 500 or 1,000 ton of LPG storage tanks. But at Bangkok depot, new storage tanks cannot be constructed because there is a limited area and a risk to encounter the massive problems in safety and environmental topics. One of rectification methods is transferring some volumes of Bangkok depot to the East, Banrongpo depot. This action can loosen much volume and reduce the risk level of shortage demand at Bangkok depot. Another depots such as Lumpang and Suratthani

depot should be monitored but not seriously because their storage tanks might be inadequate in the next 3-5 years. Moreover, PTT should concern about the number of truck loading bay especially at Banrongpo depot because its demand swiftly increases in 2002, the year of LPG price floating. At least one additional loading bay will be required in 2006; however, two shifts operation should replaced with the normal operation (8 working hours daily) from 2004 to increase LPG loading capability twice. Another location such as Sratthani depot which has truck loading bay utilization greater than 80% should be monitored closely and PTT should prepare action plans to extend its loading capacity in the far future.

BIBLIOGRAPHY

1.Ballou, Ronald H. Business Logistics Management, Third Edition: Englewood Cliffs: Prentice Hall, 1996.

2. Coyle, John J. and Edward J Bardi. The Management of Business Logistics, Forth Edition. United States of America: West Publishing Company, 1998.

3.Dilworth, James B. Production and Operation Management Manufacturing and Services, Fifth Edition. United States of America: McGraw-Hill, 1998.

4. Gattorna, John C. The Gower Handbook of Logistics and Distribution Management, Forth Edition: Australia: Gower Publishing Company, 1998.

5. Johnson, James C. and Donald F Wood. Contemporary Logistics, Fourth Edition. London: Collier Macmillan Publisher, 1990.

6. Willis, Roger F. An Analytical Approach to Physical Distribution Management: Wales: Kogan Page, 1990.