LIQUEFIED PETROLEUM GAS DISTRIBUTION PLAN TO LPG DEPOTS IN THE NORTH AND NORTHEAST BY TRAINS AND TRUCKS FOR THE PETROLEUM AUTHORITY OF THAILAND

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โดยรถไฟและรถยนต์สำหรับการปิโตรเลียมแห่งประเทศไทย

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ระบบการจัดจ่ายผลิตภัณฑ์ นับเป็นหัวใจสำคัญในการดำเนินธุรกิจปิโตรเลียม การวางแผนการจัดจ่ายที่ดี สามารถลดต้นทุนการดำเนินงานได้อย่างมีประสิทธิภาพ อันเป็นปัจจัยหลักเพื่อความอยู่รอดของธุรกิจท่ามกลางสภาวะที่มีการแข่งขันสูงเช่นปัจจุบัน

วิทยานิพนธ์นี้ เป็นการเสนอแผนการจัดส่งก๊าซหุงต้ม ซึ่งเป็นหนึ่งในผลิตภัณฑ์ปิโตรเลียมหลักของการปิโตรเลียมแห่งประเทศไทย โดยเสนอเป็นแผนการจัดส่งระยะเวลา 5 ปี (พ.ศ. 2544-2548) จากแหล่งต้นทาง คือ คลังก๊าซบ้านโรงโป๊ะ และโรงแยกก๊าซลานกระบือ ไปยังคลังปิโตรเลียมในภาคเหนือและตะวันออกเฉียงเหนือ อันได้แก่ คลังปิโตรเลียมลำปาง, คลังปิโตรเลียมนครสวรรค์ และคลังปิโตรเลียมขอนแก่น โดยใช้รถไฟ และรถยนต์ เป็นพาหนะในการขนส่ง

ในการศึกษาเบื้องต้น ได้นำหลักการของโปรแกรมเชิงเส้น (Linear Programming) มาประยุกต์ เพื่อศึกษาจำนวนพาหนะเบื้องต้นที่จำเป็นต้องใช้ในการจัดส่ง เพื่อให้สามารถรองรับปริมาณความต้องการก๊าซหุงต้มที่เพิ่มขึ้นอย่างต่อเนื่องของผู้บริโภค อย่างไรก็ตาม เนื่องด้วยข้อจำกัดบางประการอันเป็นลักษณะเฉพาะของโปรแกรมเชิงเส้น ทำให้การศึกษาดังกล่าวไม่ครอบคลุมเงื่อนไขในการปฏิบัติงานจริงบางประการ เช่น ความไม่แน่นอนของระยะเวลาที่ใช้ในการขนส่ง, ความไม่แน่นอนของปริมาณความต้องการก๊าซหุงต้มรายวัน, การชำรุดของพาหนะขนส่ง ฯลฯ ดังนั้น เทคนิคการทำแบบจำลอง (Simulation Model) จึงถูกนำมาใช้ เพื่อปรับปรุงผลการศึกษาเบื้องต้นที่ได้จากโปรแกรมเชิงเส้น เพื่อให้ผลการศึกษาที่ได้ มีความสอดคล้องกับเงื่อนไขในการปฏิบัติงานจริงมากยิ่งขึ้น

จากการใช้เทคนิคการทำแบบจำลองพบว่า เพื่อให้สามารถรองรับปริมาณความต้องการก๊าซหุงต้มที่คาดว่าจะเพิ่มสูงขึ้น ในระยะเวลา 5 ปี ควรมีการลงทุนซื้อรถไฟเพิ่มจำนวน 3 ขบวน โดยให้รถไฟเข้าสู่ระบบในปี พ.ศ. 2547 และจากการวิเคราะห์ความไวพบว่า ทางเลือกดังกล่าวจะยังคงเป็นทางเลือกที่เหมาะสม หากปริมาณความต้องการก๊าซหุงต้มเบี่ยงเบนไปจากปริมาณที่คาดการณ์ไว้ภายในช่วง –3% ถึง +5% ทั้งนี้หากปริมาณความต้องการก๊าซหุงต้มเบี่ยงเบนต่ำกว่าปริมาณที่คาดการณ์ไว้มากกว่า 3% การทยอยซื้อรถไฟจำนวน 2 ขบวน ในปี พ.ศ. 2547 และอีก 1 ขบวนในปี พ.ศ. 2548 จะเป็นทางเลือกที่มีความเหมาะสมมากกว่า และหากปริมาณความต้องก๊าซหุงต้มเพิ่มขึ้นมากกว่าที่คาดการณ์ไว้เกิน 5% การลงทุนซื้อรถไฟเพิ่มจำนวน 3 ขบวน ในปี พ.ศ. 2547 และอีก 1 ขบวนในปี 2548 จะเป็นทางเลือกที่มีความเหมาะสมมากที่สุด

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Product distribution system is a crucial part of running petroleum business. A well-planned distribution system significantly reduces an operating cost which is the most important issue for survival amongst high competition like nowadays.

As a result of this thesis, the LPG distribution plan by rails and trucks from supply sources, Banrongpoh Depot and Lankrabue Gas Separation Plant, to LPG Depots in the North and Northeast, Lampang, Nakornsawan, and Konkhaen Petroleum Terminal, is done for the Petroleum Authority of Thailand for a five-year-period (year 2001-2005).

Linear programming theory is applied as a primary study to figure out the primary quantity of transporters required in order to sufficiently serves the continuously increased demand. Nevertheless, some special characteristics of the linear programming itself are not compatible with some conditions of the real world operation such as fluctuation in transportation lead time, fluctuation in demand, transporter's failure rate, etc., the simulation study is then conducted to make the primary result more practical.

From the simulation technique, three rails should be added into the system in the year 2004. Furthermore, a sensitivity analysis shows that if the demand deviates within the range of –3% to +5%, this alternative will still be the optimal solution. In case the demand is lower than the expected amount greater than 3%, two rails should be invested in the year 2004, and another one rail in the year 2005. On the contrary, if the demand is larger than the forecasted amount more than 5%, the optimal solution is to invest in three rails in the year 2004 and another one rail in the year 2005.

Department The Regional Centre for Manufacturing Systems Engineering Student's signature ______________

Field of study Engineering Management Advisor's signature ______________

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CHAPTER 1

INTRODUCTION

Here, in this chapter, primary details are provided for a better understanding of the contents of the thesis. First of all, a general profile of Petroleum Authority of Thailand (PTT) is provided to give a general perception about PTT. After that, a background of LPG distribution system of PTT is discussed. Next, problems found in the existing distribution system are pointed out in order to be solved by a solving method conducted in this thesis. Objective and scope are identified in order to give a borderline of the research. Methodology applied is set step by step. Finally, the expected result is established as an output of the thesis.

1.1 A General Profile of PTT

1.1.1 A History of PTT

Petroleum Authority of Thailand (PTT) was founded in 1978 as a national oil company. At that time, there was a second world oil crisis caused by a war between Iraq and Iran. Both Iraq and Iran are major oil countries that are members of the Organization of Petroleum Exporting Countries (OPEC). The war made a price of crude oil increased rapidly. Therefore, Thailand had to face an enormous energy crisis inevitably. The oil supply, refining, and distribution business was virtually all in the hands of multinational companies. The country was struggling hard to procure petroleum to sufficiently serve domestic demand. The Fuel Organization under the Ministry of Defense as the only public agency in the oil business at that time could not implement the government's policy effectively enough. In order to increase Thailand's ability to solve petroleum problems with unity and efficiency, therefore, Petroleum

Authority of Thailand was established on December 29th, 1978 as a state enterprise under the Ministry of Industry to conduct and promote the petroleum and related businesses for the maximum benefits to the country and all Thais.

1.1.2 Vision of PTT

To be a national energy enterprise that meets world class standards by undertaking petroleum related businesses including other value-added businesses both domestically and internationally by striving to create the highest value for the organization through combining commercial objectives and government policy.

1.1.3 Goal of PTT

To be a world class company by the year 2000.

1.1.4 An Organization Structure of the Entire PTT

At the beginning, PTT has an organization type of a functional type. However, on January 1st, 1992, PTT was reorganized to a business-oriented type. The new organization structure is conformed to the operation in a commercial-oriented role significantly. The mechanism of the management policy was decentralized to the responsible sectors entitled “Sector Group”. The new corporate structure consists of four sector groups as follows:

1. Exploration, Production and Gas Sector Group
2. Downstream Oil Sector Group
3. Refining Sector Group
4. Petrochemical Sector Group

The organization chart of the entire PTT is shown in figure 1.1.

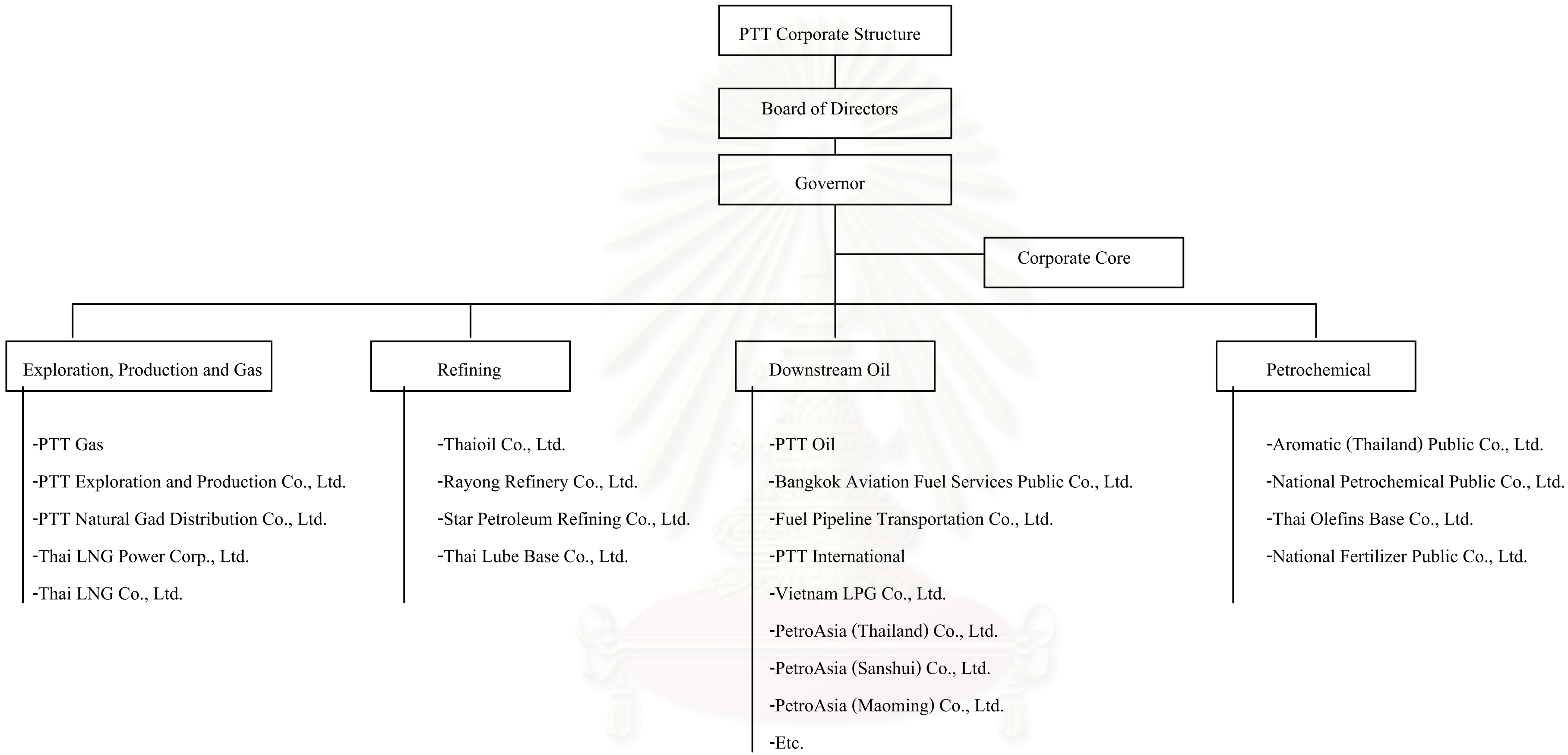

Figure 1.1: Organization Chart of the Entire PTT

Source: PTT Oil Intranet

The supervision and management are decentralized to sector groups. Each sector group is supervised and managed by Sector Group Head, an executive from Head Office who represents PTT in the Board of Directors and joins in the formulation of management objectives as well as directs the administration and management of all the sector groups to be on the same course. Therefore, benefits within the sector group are attuned. It is a significant mechanism in creating business strength. This has resulted in more flexibility and precise performance evaluation and also business capability.

Each sector group consists of business units as shown in figure 1.1. Each business unit is equipped with independent operation and its own means of harmonizing benefits into a network which result in the best creation synergy in each line of business and also within the sector group.

However, almost all the activities mentioned in this thesis are involved with PTT Oil Business which is addressed in the Downstream Oil Sector Group. Hence, an organization chart of PTT Oil is going to be focused on.

1.1.5 An Organization Structure of PTT Oil

In figure1.1, Downstream Oil Sector Group consists of 3 main business groups, PTT Oil, PTT International, and Subsidiaries, Affiliated and Minor Shareholding Companies. As illustrated in figure 1.2, PTT Oil consists of 7 departments as follows:

1. Accounting and Finance
2. Planning
3. Human Recourses
4. Terminal Operations
5. Supply Chain Management
6. Commercial Marketing
7. Retail Marketing

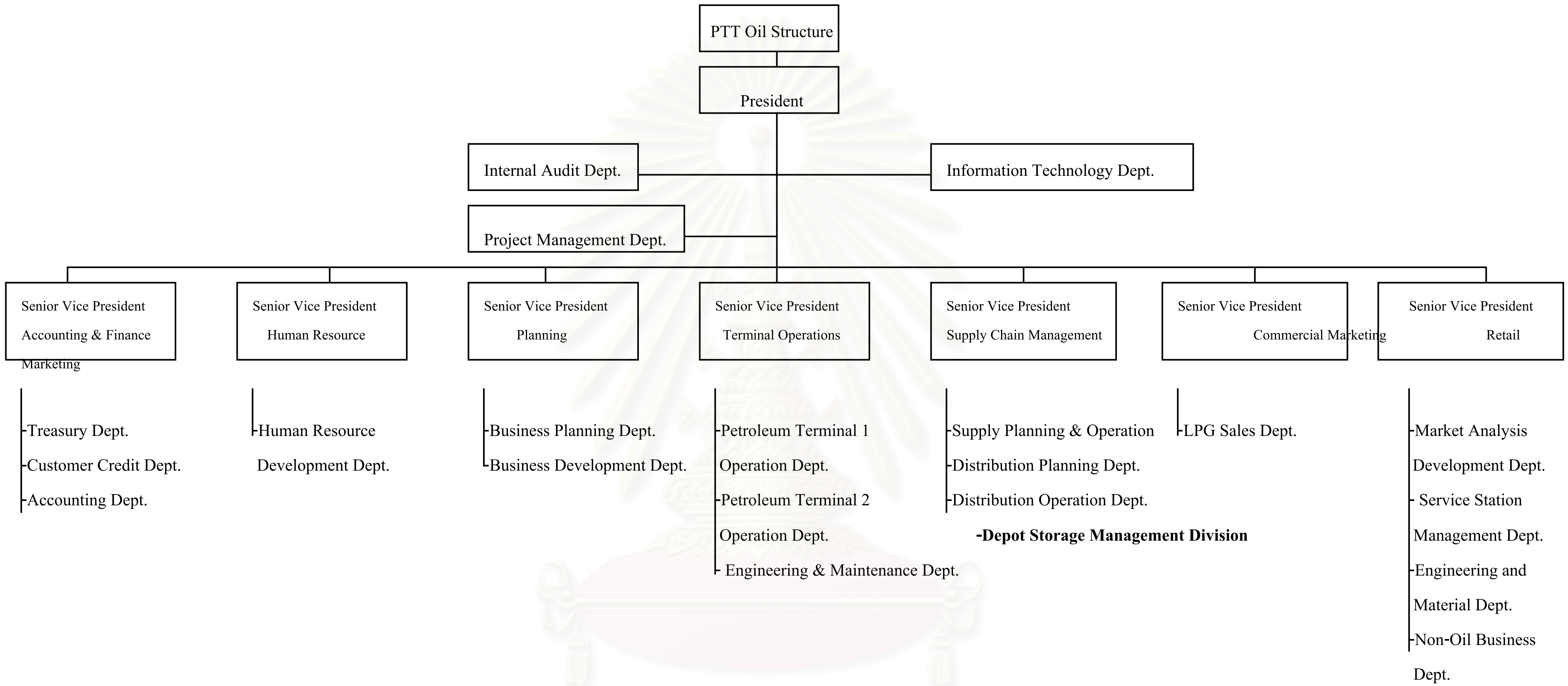

Figure 1.2: Organization Chart of PTT Oil Business

Source: http://www.ptt.or.th

1.2 Background of LPG Distribution System of PTT

In order to be competitive in a long term, all activities of every business must be well planned and properly managed. PTT as a leader in the Petroleum Business in Thailand is the one that is highly considering about maintaining its leadership in the long-term future.

Logistic Operation in Supply Chain Management is one of PTT's key functions. It directly affects an operating cost, which is the most important issue for being competitive. Logistic operation must be carefully planned and managed to maximize the existing resources and generating the highest benefits towards the organization as a whole.

Liquefied Petroleum Gas (LPG) is also a major product of PTT besides oil products. LPG is a composition of approximately 60% of C_3 (Methane) and 40% of C_4 (Butane) by weight. It is mainly used in a household cooking, in an industry as a fuel, and as an engine gas for taxis and three-wheel vehicles. LPG consumed in Thailand is domestically produced from gas separation plants and also from the refineries.

LPG distribution system of PTT consists of 4 main elements: a supply source, a distribution center, a destination LPG depot, and transportation equipment.

As previously stated, PTT's LPG supply source are domestic gas separation plants and domestic refineries. PTT has its own 4 gas separation plants. Three of them are located at the same area in Rayong province (GSP Rayong) and the last one is in Khanom district, Nakornsrithammarat province (GSP KNM). Moreover, there is another gas separation plant that supplies LPG to PTT's system called Lankrabue Gas Separation Plant (GSP LKB). It belongs to Thai Shell Exploration and Production Co., Ltd, established in Lankrabue district, Kumpaengpetch province. For the refineries, there are 4 refineries involved: Bangchak Petroleum Public Co., Ltd. (BCP), Thaioil Co., Ltd. (TORC), Star Petroleum Refining Co., Ltd. (SPRC), and Rayong Refinery Co., Ltd. (RRC).

For a distribution center, PTT has 2 terminals operating for this purpose. The first one named Banrongpoh Terminal (BRP) is a rail and truck distribution center. Another one is called Kao Bor Ya or Marine Terminal (MT). MT is a marine or vessel distribution center. Both BRP and MT are located in Chonburi province.

In every region of Thailand, there are LPG depots of PTT scattering all over the areas: Konkhaen depot (KKN), Lampang depot (LMP), Nakornsawan depot (NSW), Suratthani depot (SRT), Songkhla depot (SKL), and Bangchak depot (BCK) in Bangkok.

In order to operate LPG distribution system, there are 4 modes of transportation equipment involved. They are pipeline, vessel, rail, and truck. Each mode is utilized according to a geographical suitability of each destination depot.

The following figure is a map to roughly illustrate a location of each supply source, distribution center, and destination depot of PTT.

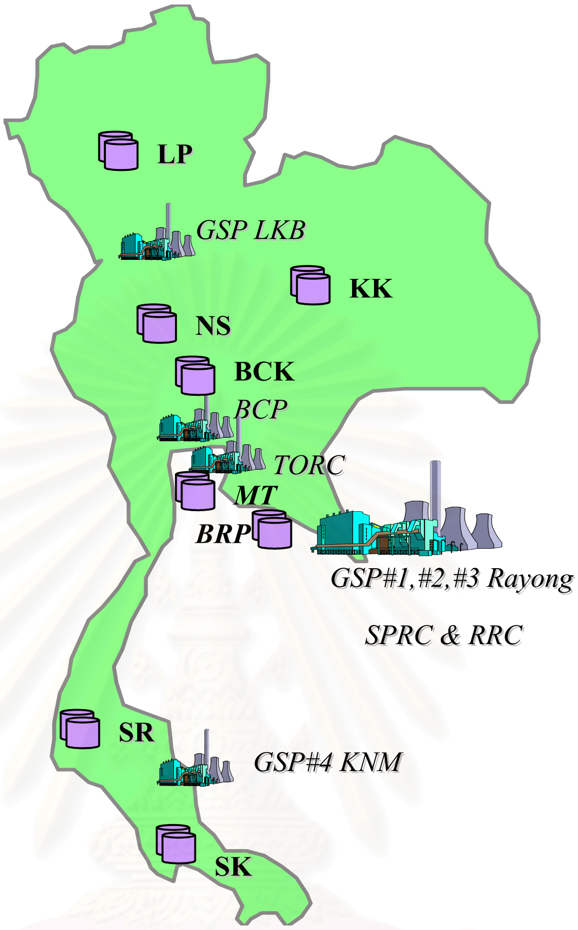

Figure 1.3: Location of Each Supply Source, Distribution Center, and Destination Depot of PTT

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

For the LPG distribution system of PTT, it can be divided into 3 groups as shown in figure 1.4, on the next page. The first group is supplying to the two distribution centers. LPG is transferred through a pipeline system from GSP Rayong to MT and BRP in Chonburi. The second one is supplying to BCK, SRT, and SKL. For BCK, it normally receives LPG from MT and the 4 refineries: BCP, TORC, SPRC, and RRC. A vessel is a main carrier transporting LPG from the supply source to BCK except for supplying from BCP that is done through a pipeline. For the two depots in the South: SRT, and SKL, LPG is transported by vessel mainly from GSP KNM and sometimes from MT. The last group is supplying to KKN, LMP, and NSW by rail and truck from BRP. In addition, LPG is also sent from GSP LKB by truck to these depots.

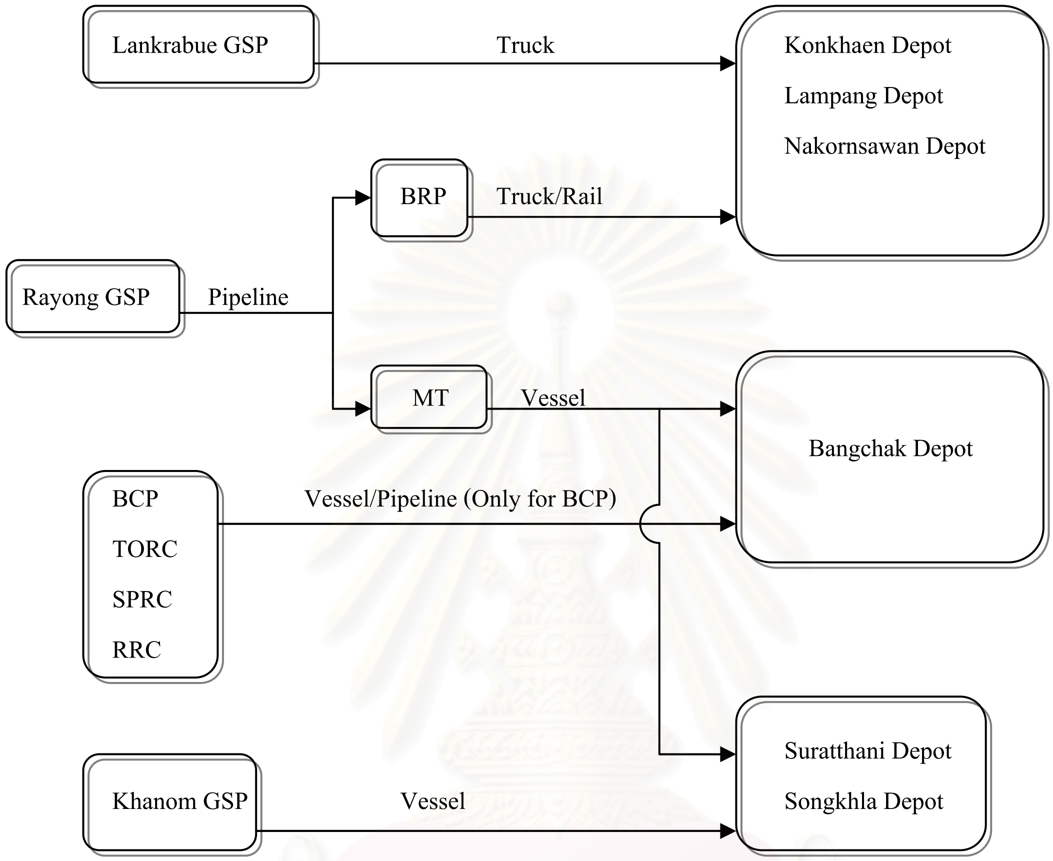

Figure 1.4: LPG Distribution System of PTT

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

In the last group, there are some problems that are going to be focused in this thesis. Details of them will be described in the next part.

1.3 Problem Statement

As previously stated, the problems occur in the last group of transportation, transportation from GSP LKB (only by truck) and transportation from BRP (by rail and truck) to KKN, LMP, and NSW. The problems can be divided into 2 parts as follows:

1. In the existing system, the LPG distribution schedule of both rail and truck is done according to only the experience of the scheduler. There is no scientific method to help judging whether or not the existing system is appropriate or it is done in the logical way. This may result in a high transportation cost or a low rate of resource utilization. The experience of a scheduler is the only thing that indicates the suitability of the existing system at the present. There is no systematic methodology to be used as a guideline to help setting the LPG distribution schedule.

2. Customers' demand is continuously growing. The existing amount of transportation equipment seems no longer be able to cope this growing demand. An additional amount of transportation equipment required to serve the demand in the future must be planned as early as possible because it is a long process to buy new transportation equipment or to search for new transportation contractors. At the present, there is no scientific guideline or suggestion about a suitable amount of transportation equipment required in the future. The proposed distribution plan for the future is now done by, again, the scheduler using his own personal experiences.

1.4 Objective

The objective of this thesis is to propose LPG distribution plan for LPG depots of PTT in the North and Northeastern: KKN, LMP, and NSW. The plan will be proposed for a five-year-period consisting of LPG volume transported from each supply source to each LPG depot by each mode of transportation equipment together with a quantity of each type of transportation equipment required for operating that proposed distribution plan.

1.5 Scope

1. This thesis will focus on only the LPG distribution system to the LPG depots in the North and the Northeast: KKN, LMP, and NSW.

2. The transportation equipment used includes only rail and truck.

3. The supply sources involved are BRP and GSP LKB.

4. The LPG distribution system stated in this project means transporting LPG from the supply sources stated above to the mentioned LPG depots excluding the deliveries from the depots to customers.

1.6 Methodology

1. Analyze all the details about the problems to provide a clear understanding of the problems.

2. Collect, analyze, and document all the necessary data to make them easy for use in solving the problem.

3. Find out a suitable technique to solve the problem e.g. a quantitative method, a linear programming, a simulation, etc.

4. Validate the conceptual model to ensure that it properly works in a real situation.

5. Use a conceptual model to find out an alternative for a distribution plan in the future.

6. Analyze, interpret the results run from the model.

7. Select an appropriate alternative, document it into a suitable form, and propose this alternative as a distribution plan for the future.

1.7 Expected Result

The expected result of this thesis is a Proposed LPG Distribution Plan for the LPG depots of PTT in the North and Northeast for a five-year-period. This plan is set according to the result run from a decision model. It will consist of the LPG volume that will be transported by each mode of transportation equipment from each supply source to each destination depots. Moreover, a proposed quantity of each type of transportation equipment that PTT should provide in advance in order to serve the increased demand according to the proposed plan will be also provided to facilitate the procurement planning.

All the details described previously are guidelines that generate a primary understanding of the thesis. In the next chapter, related literature surveys will be discussed as a source of ideas to solve the problems.

CHAPTER 2

RELATED LITERATURE SURVEY

The followings are theory that may be beneficial for accomplishing the research. They are general ideas that can be applied to help solving the problems.

2.1 General Idea about Management Science

2.1.1 Anderson, Sweeney, and Williams

Management science is an approach to a decision-making based on the scientific method. Nowadays, computers play a vital role in enabling practitioners to use the methodological advances to successfully solve a variety of problems. A decision making process may take on two basis forms: qualitative and quantitative. Qualitative analysis is based primarily on the operator's judgement and experience. It includes the intuitive feel for the problems. Moreover, it is more an art than a science. It is suitable if the operator has high experience or if the problem is simple. On the other hand, if the operator has little experience or if the problem is extremely complex, a quantitative analysis is an important tool to help making a decision. When using the quantitative approach, an analysis will concentrate on the quantitative data associated with the problem and develop mathematical expressions that describe the objectives, constrains, and other relationships that exist in the problem. However, the integration of the quantitative solution with qualitative consideration is the best decision making. Linear programming is a problem-solving approach that has been developed to help the operator make decisions. It involves with maximizing or minimizing some quantity i.e. cost, time, etc. In all linear programming problems, the maximization or minimization of some quantity is the objective.

Simulation is the process of studying the behavior of a real system by using a model that replicates the behavior of the system. A mathematical expressions and logical relationships describe how the system operates. A computer is used to perform the computation required by the simulation model. It is one of the most frequently used techniques of management science. When a system is complex, simulation may be the best and perhaps the only way to model the system.

2.1.2 Pidd

There are various types of models that are used in management science. They are representations of the system of interest and are used to investigate possible improvement in the real system or to discover the effect of different policies on the system. Realistic simulations may require long computer programs of some complexity. Producing useful results from a computer simulation sometimes requires a time-consuming process. Therefore, a computer simulation should be regarded as a last resort. It should be used if all else fails. However, there are certain advantages in employing a simulation approach in management science and it may be the only way of tackling some problems. It generates many benefits in terms of cost, time saved from repeated activity, safety, and legality. About the mathematical model, most mathematical models cannot fully cope with dynamic or transient effects and it is debatable.

In order to visualize the operations of the entities moving within a simulation model, an activity cycle diagram is one approach used to fulfill this requirement. Though it cannot include the full complexity of a system being simulated, it does provide a skeleton which can be enhanced later.

There are only two symbols used in activity cycle diagram as shown in figure 2.1: an active state symbol and a dead state symbol.

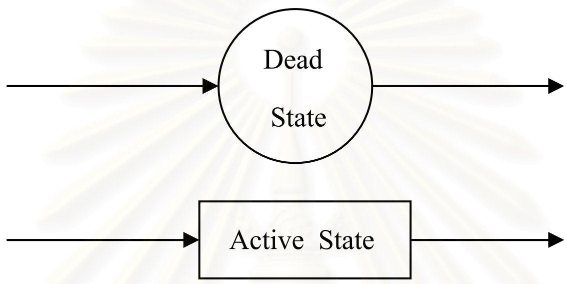

Figure 2.1: Symbols for Activity Cycle Diagram

Source: Michael Pidd, 1998, Computer Simulation in Management Science, Fourth Edition, John Wiley & Sons, Chapter 4, page 47

Activity diagram is a map which illustrates the life history of each class of entity and graphically displays their interactions. Each class of entity has its own life cycle which consists of a series of states. The entities move from state to state as their life proceeds.

An active involves the co-operation of different classes of entity. The duration of an active state can always be predictable in advance. On the contrary, a dead state involves no co-operation between different classes of entity. Generally, it is a state that the entity waits for something to happen.

In order to build a discrete simulation model, it is necessary to complete the following steps:

- Identify the important classes of entity
- Consider the activities in which they engage
- Link these activities together

2.1.3 Vijit, Wanchai, Charoon, and Chuvej

Flow process chart was originated by Frank B. Gilbreth. It is a tool used to present the operation in a logical form. The more material and people involved, the more complex the chart is. Processes occur in a system can be described by using a set of standard symbol which consists of five major symbols as follows:

⇨ means transportation

D means delay or waiting

▽ means storage

○ means operation

□ means inspection

2.1.4 MacCarthy

Operation research or Management science is the discipline which advocates rational methodologies for management decision problems. Simplex algorithm is a general procedure to optimize limited resources to achieve a certain objective under constrained conditions. Most problems are unique but many categories of problems have similar features. At the definition stage, the boundaries of the problems must be identified and set. There may often be re-defined later. Objectives must be clarified in broad term. Measure of effectiveness must be set. Problem definition will also include the identification of factors, variable, and data relevant to the problem and their nature. Modeling is a key feature in the Operation research or Management science methodology. Next, validation will be run to optimize the result. Sensitivity analysis should be studied to generate more understanding about the result. In a phase of implementation, both pilot and full implementation are necessary.

2.2 Linear Programming Theory

In the world of mathematical decision tools, linear programming (LP) is the most widely used, Frank et. al. (1988). In this section, major issues of LP are discussed to provide a general concept of LP.

2.2.1 What is LP?

LP is defined as a decision tool that determines the best allocation of limited resources such as capital, labor, raw material, time, etc. It is a subset of mathematical programming which concerns with development of modeling and solution procedures in order to maximize the extent to which the goals and objectives of the decision- maker are related, Thomas et. al. (1993). LP deals with modeling a problem and then solving it by mathematical techniques that will minimize or maximize a linear function subjected to a system of linear constraints. In other words, LP is setting up and solving a system of equation. Nowadays, in solving a system of linear equation, computer plays a vital role in doing that.

2.2.2 LP Model

LP model consists of a linear objective and a system of linear constraints. A form of LP model is illustrated as follows:

Maximize/Minimize $a_{11}x_1+a_{12}x_2+\ldots\ldots\ldots+a_{1n}x_n \leq b_1$ (1)

Subject to constraints $a_{21}x_1+a_{22}x_2+\ldots\ldots\ldots+a_{2n}x_n \leq b_2$ (2)

$a_{m1}x_1+a_{m2}x_2+\ldots\ldots\ldots+a_{mn}x_n \leq b_m$

and $x_1 \geq 0, x_2 \geq 0, \ldots\ldots\ldots\ldots\ldots, x_n \geq 0$ (3)

Therefore, LP problem may be defined as any problem whose mathematical formulation fits this form of general model.

The first component of LP model is shown in equation (1), an objective function. It is a mathematical expression that measures the effectiveness of a particular solution for the LP problem, or in other words, it is a goal of a decision-maker.

The second element of the LP model is a set of constraints, addressed in equation (2). Sometimes, they are also called structural constraints. A set of these constraints specifies a limitation of resources that must be met while finding the optimal solution. For the equation (3), it is called nonnegativity condition which means that the variables must be restricted to either zero or positive value.

The x_j variables are decision variables. The value of them are determined when the LP model is solved in order to figure out an optimum solution. Their values are the answer of the LP model.

a_{ij}, x_j and b_i shown in the general LP model are called parameters. They are input data constants required by the LP model. They present the relationship among various variables in both an objective function and constraints.

2.2.3 Formulating LP Model

Thomas et. al. (1993) claimed that LP model building is more an art than a science. Hence, formulating LP model greater depends on the model builder's own ingenuity and experience. The art of problem formulation comes with patience, practice, and a suitable framework for addressing problems. LP is an attempt to represent the essence of some problems in terms of relationships among symbols. Interactions among variables of the real system are translated into mathematical equation.

Frequently, formulating LP model can be the most difficult part of an LP analysis. Though, it is the hardest, it is the most important part.

Davis et. al. (1986) suggested that before directly going to construct a mathematical structure, trying to describe the problem verbally makes formulating LP model much easier. Firstly, an overall objective should be established. After that, a problem objective and how the objective is related to the decision factors should be figured out. Lastly, each constraint should be identified verbally. When a verbal part is finished, the next step is to transform the verbal descriptions into a proper mathematical structure.

According to Thomas et. al. (1993), there are some clues for constructing LP models as follows:

1. Understand the problem. It is necessary to ensure that the problem is fully understood before constructing the model.

2. Identify decision variables. As discussed that the optimum value of the decision variables is what a decision-maker looking for from the LP model, wrong defining of decision variables may lead to developing an invalid model.

3. Choose a numerical measure of effectiveness for the objective function. A model developer must identify what is a quantitative criteria in judging the effectiveness of the system.

4. Represent the measure of effectiveness as a linear expression involving the decision variables. Components of the quantitative criteria addressed should be illustrated in terms of linear relationship.

5. Identify and represent all constraints as linear expression involving decision variables. Constraints for each limited resource must be established. All decision variables that effect the scarce resources must be completely counted. Not only the limited resources that must be defined as a constraint, but other types of constraints such as technical specification, technical requirement, management policy, demand, etc. must also be concerned and defined. After that, relationships among the decision variables must be presented in form of linear expression for each constraint.

6. Collect data or make appropriate estimation for all parameters of the model. All parameters of the model must be defined as numerical constants. In case that a decision maker cannot determine an exact value for some parameters, a specific numerical values must be estimated and designed to complete constructing LP model and make it be able to run because only specific values can be used in solving an LP model. For the case that a parameter is only an estimated value, a sensitivity analysis should be applied in order to explore the effects of changing some parameters over a range of values. Normally, collecting data is often the most time-consuming phase.

2.2.4 Solving Method of LP Model

When the LP model is completely constructed, the next step is to find out the optimum answer by solving the model mathematically. Theoretically, an LP model can be solved by hand applying various types of mathematical method such as direct elimination method, mathematical deduction method, graphical method, general algebraic method, simplex method, big M method, two-phase method, and so on. However, in real working environment, the LP model involves in a large number of variables and constants. Solving it by hand seems impossible and is unheard of, Frank et. al. (1988). In actual application, computer is used as a solving tool inevitably.

There are many software packages used to support the solution of LP problem on a microcomputer such as LINDO, QS, Microsoft Excel Solver, etc. These packages are user-friendly facilitating solving an LP model. Generally, these packages are sophisticated simplex-based procedures. With these LP packages, users just concentrate on the recognition of an LP problem, its formulation, its underlying assumption, and its preparation for submission to a computer, and interaction of outputs

Frank et. al. (1988) suggested that for a computer-based solution, there are 3 main areas that should be focused on.

1. Model formulation. A model builder should study as mush as possible about the LP software package going to be used in order to properly construct the model according to the format specified by that software package. For example, all variables must be placed on the left-hand side of the constraints, all constants must be placed on the right-hand side of constraints.

2. Preparing input. At this phase, a model builder must exactly know how to access and run the appropriate program. The following inputs are generally specified: maximize or minimize condition, a number of real variables, a number of constraints, a number of constants.

3. Interpreting output. When output is generated from the LP software, it should be focused on the following areas:

- An optimal value of the objective function.
- An optimal value of each variable.
- An optimal value of supplemental variables.

Focusing on these areas makes interpreting done more easily and effectively. Furthermore, the output may have abnormal characteristics that should be noticed such as no feasible solution or null solution space, unbounded solution space, redundant constraint, alternative optima, degenerated optimal solution, etc. These abnormal characteristics should be noticed and marked in mind of an interpreter in order to provide a correct interpretation of the output.

2.2.5 Special Characteristics of LP Problem

It is necessary to exactly understand characteristics and limitations of LP model. Otherwise a misunderstanding may lead to misusing of the LP model.

Generally known that LP has a single goal and all restrictions are linear in nature. As a result of these conditions, the LP model has two basic properties: certainty and linearity.

2.2.5.1 Certainty

LP is deterministic because all parameters of the model must be known and fixed as a constant. If any of the parameter cannot be exactly identified, an estimation of these parameters might be addressed with a helping hand of a sensitivity analysis as described previously.

2.2.5.2 Linearity

Linearity of LP is that the relationship between dependent and independent variables can be presented by straight line. The linearity is a result of proportionality, additivity, and divisibility.

1) Proportionality

The amount of each resource used must be proportional to the value of the decision variable. For example, in an objective function to maximize profit $5x_1 + 2x_2$, each unit of x_1 contributes \$5 (a proportional amount) to the value of the objective function.

2) Additivity

It means that the total contribution of all activities is identical to the sum of the contributions for each activity individually. For example, for the objective function $5x_1 + 2x_2$, if the output of x_1=1 and x_2=1 is generated, as a result of additivity, the total profit is then equal to 7, a contribution of 5 and 2.

3) Divisible

Decision variables are allowed to assume a continuous range. Therefore, integer is not provided. It is necessary to approximate the answer by rounding off the solution to integer. This may result in departure from optimality. Integer programming may be applied instead of LP in case that optimal integer solution is required. However, this type of application is beyond the scope of this content.

2.2.6 Application of LP

Whenever a problem is looked at as a matter of effectively allocating scarce resource, LP is often selected as a mathematical decision tool. A greater efficiency of nowadays computer makes LP becomes more popular. LP is applied in various working fields such as in industrial, agricultural, military application, etc.

Identified by Thomas et. al. (1993), LP is applied in physical distribution problem. In physical distribution problems, LP is used to determine the shipping pattern that minimizes shipping costs while all demands are met and other supplies and limited transportation capacities are not exceeded. This application is somewhat similar to the case of LPG distribution system which is going to be studied in this thesis.

2.2.7 Sensitivity Analysis

Sensitivity analysis is the study of how changes in the coefficients of a linear program affect the optimal solution, Anderson et. al. (1994). It does not begin until the optimal solution to the original linear programming problem has been obtained. Consequently, in other words, sensitivity analysis is often called postoptimality analysis. Sensitivity analysis is important to decision makers because real problems exist in a dynamic environment. Working in such environment, some coefficients should be expected to change over time. Therefore, how such changes affect the optimal solution is beneficial for making a decision. Sensitivity analysis creates the information needed to respond to the changes without requiring the complete solution of a revised linear program. Sensitivity analysis may be conducted by changing the coefficient of the objective function or that of the linear constraint. Moreover, it can be done by altering the value in the right hand side of the constraints as well.

2.3 Simulation Theory

In this section, general concepts of simulation are discussed to provide a basic idea before applying simulation in solving a problem.

2.3.1 What is Simulation?

Defined by Pegden et. al. (1995), simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.

According to Anderson et. al. (1997), a simulation study is a process of understanding a real system behavior by using a model that replicates the behavior of the system. A simulation model is a logical relationship that mimics reality.

Supported by Kelton et. al. (1998), simulation refers to a broad collection of methods and applications to mimic the behavior of real system, usually on a computer with appropriate software. In fact, "simulation" can be an extremely general term since the idea applies across many fields, industries, and applications. These days, simulation is more popular and powerful than ever since computers and software are better than ever.

With the simulation, the behavior of system can be described. Computer simulation involves experimentation on a computer-based model of some system, claimed by Pidd (1998). The model, as a vehicle for experimentation, often behaves in a trial and error manner in order to illustrate the effects of various policies. The policy that gives the best result identified by the model will be implemented in the real system. Furthermore, the simulation allows constructing theories or hypotheses that account for the observed behavior and also allows predicting future behavior. The experimentation generally answers 'what if' questions. A figure 2.2 below demonstrates the concept of this idea.

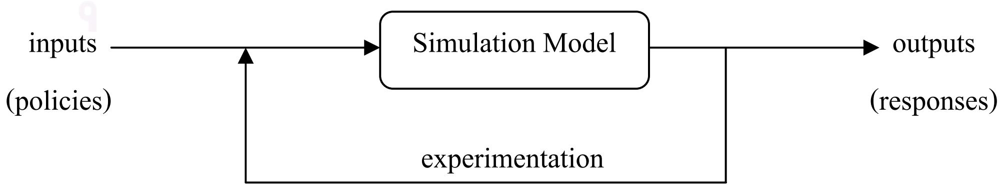

Figure 2.2: Simulation as Experimentation

Source: Michael Pidd, 1998, Computer Simulation in Management Science, Fourth Edition, John Wiley & Sons Ltd., Chapter 1, page 5

Simulation is one of the most powerful analysis tools applied with those for the design and operation of complex processes or systems. It is no longer regarded as the approach of "last resort". Nowadays, it is viewed as an indispensable problem-solving methodology.

2.3.2 Simulation Model

Pegden et. al. (1995) classified a simulation model as iconic or symbolic. An iconic model is sometimes called a scale model. It looks like the real system using primarily for training purpose e.g. flight simulators, driving simulators, etc. For a symbolic simulation model, it mimics the properties and characteristics of the real system in mathematical and/or symbolic form. Generally, a symbolic simulation is run on a computer. Nowadays, computer becomes extremely essential in conducting a simulation. The model constructed in this thesis is a symbolic simulation model.

2.3.3 Time Handling in Simulation

As the simulation proceeds, a computer-programmed simulation clock keeps track of time, claimed by Anderson et. al. (1997). There are two approaches for advancing the simulation clock called the fixed-increment time advance method and the next-event time advance method.

For, the fixed-increment time advance method, as shown in figure 2.3, the simulation clock is advanced with a fixed increment of time such as a minute, hour, day, month, or other convenient periods of time for the system being simulated. The length of fixed increment of time must be taken before the simulation is carried out. The status of the system is reviewed at each time movement and the state of the system is updated whenever an event corresponds to the current time increment. Hence, if the increment period of time is too long, the behavior of the model is then coarser than that of the real system because some of the state changes that occur cannot be shown. On the contrary, if the increment period of time is too small, the model is frequently reviewed unnecessarily resulting in excessively long computer run.

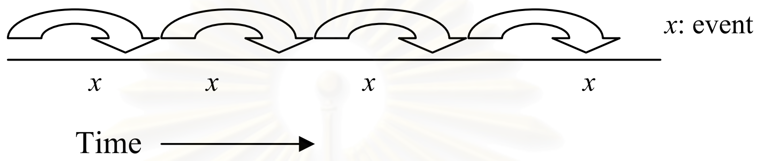

Figure 2.3: Advancing Time Using the Fixed-Increment Time Advance Method

Source: Hoover, S., V. and Perry, R., F., 1990, Simulation: A Problem-Solving Approach, Addison-Wesley Publishing Company, Inc., USA., page 71

For the next-event time advance, it is applied by most major specific simulation language and by most people using a general-purpose language. As shown in figure 2.4, the simulation clock is advanced to the time of the next occurring event. The state of the system is updated depending upon what happens to the system when the event occurs. Therefore, the increment period of time varies and depends upon when the simulation events occur.

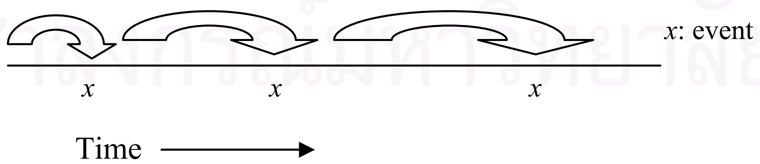

Figure 2.4: Advancing Time Using the Next-Event Time Advance Method

Source: Hoover, S., V. and Perry, R., F., 1990, Simulation: A Problem-Solving Approach, Addison-Wesley Publishing Company, Inc., USA., page 71

Pidd (1998) gave a comment that the next-event time advance method is more general than the fixed-increment time advance method since if the events in the simulation system occur at the a regular interval, the next-event time advance methods then behaves as if it were a fixed-increment time advance method. In other words, a fixed-increment time advance method is a next-event time advance method whose the next event occurs at a regular method.

2.3.4 Stochastic Model and Deterministic Model

There are 2 types of simulation models: Deterministic and Stochastic simulation model. According to Kelton et. al. (1998), models that have no random input are deterministic. It ignores the influence of random or unpredictable variables in the environment or in its own components. On the other hand, stochastic models operate with at lease one random input. It tries to capture the important random components of the system and describes the behavior of a system through the time.

Therefore, a behavior of a deterministic system is totally predetermined while that of a stochastic system is just about how likely certain events are to occur. However, the process of building both of these two types is the same. In addition, for a stochastic model, a suitable probability distribution or probability expression must be selected to represent the variable of the random inputs. Results are dependent on the sample taken. Hence, it is usual to make several simulation runs, each with a distinct sampling pattern, before drawing any conclusion, Pidd (1998). Thus, The user must consider carefully in interpreting the output of the stochastic simulation. That's a reason why it is said that the results of stochastic simulation are more difficult to interpret than those of the deterministic model. In fact, a model can have both deterministic and random inputs in different components.

2.3.5 Discrete Change and Continuous Change

In a discrete model, change can occur only at separated points in time. On the contrary, the state change of a continuous model can change continuos over time. However, a simulation model can have elements of both discrete change and continuous change. This type of model is called mixed continuous-discrete model.

2.3.6 Selecting Simulation Software

Suggested by Pidd (1998), selecting simulation software should be examined case by case. Each problem has its own special characteristics and requirements. A suitable software significantly facilitates conducting simulation.

2.3.6.1 Criteria Used in Selecting Simulation Software

In order to select an appropriate software to be exploited, there are some factors that should be concerned as criteria.

1) The Type of Application

It is a fact that there is no simulation software that is suitable for any type of application. In other words, there is no software that can be a magic solution for every case. Each software has both strengths and weaknesses at the same time.

For example, software that is intentionally designed for the simulation of manufacturing system may not be appropriate to be applied with simulating an airport. However, it does not mean that such dedicated packages cannot be used for applications outside their main application domain but the analyst may need to think rather creatively about how to implement the actual system within the set of options provided by the software package.

2) The Expectation for End-Use

It is necessary to know how the simulation model will be used when it is completed. If a model will be used by the analyst who develops the model himself, animation may not be much concerned to attract the user. Just it can produce the correct result may be enough. On the other hand, if the model will be run by the client who may run the simulation unaided, the ease of run and graceful, friendly operation are now crucial.

3) Knowledge, Computing Policy and User Support

A simulation software would be chosen in the light of an organization's software policy. A software product needs to be supported by someone within the organization and also by the vendor. Consistency and standardization is required when planning software purchases. A software vendor should be able to provide an efficient after-sales support.

4) Price

Price of simulation software varies in a wide range. There is no guarantee that the most expensive software are better or have a wider application range than the cheaper one has. A more expensive product may be worthwhile if it significantly reduces the time to develop and implement a valid simulation. Generally, the vendor includes a charge of the after-sales support and training into the selling price. Hence, buyers have to judge how much they need these supports and training.

2.3.6.2 Type of Simulation Language

Simulation software in the existing market can be categorized into 2 main types as follows:

1) Programming Approach in General-Purpose Language

General-purpose computer programming language such as BASIC, FORTRAN, PASCAL, and C can be used to develop a computer program that will model the system and perform the simulation computation. These general-purpose languages have an advantage in that they can generate a highly specific system that cannot be modeled properly by simulation software package. However, working with these approaches is time consuming and cost generating.

2) Programming Approach in Simulation Language

A simulation language differs from a general-purpose language in that a general-purpose language does not have a simulation-oriented syntax which allows doing with simulation task much easier. GPSS, SIMAN, SIMCRIPT and SLAM are examples of these simulation languages. They facilitate the process of writing the computer program of simulation model. Moreover, they have automatic or built-in simulation clock which simplifies procedure for generating probabilistic components, and they also have procedures of collecting and summarizing the simulation data. Later, a concept of a block structured system are developed e.g. GPSS, SIMAN, etc. in order to unable non-programmer to develop simulations. These make modeling the simulation model even easier.

2.3.7 Model Verification and Validation

In doing simulation, it is necessary to confirm that the simulation model accurately describes the behavior of the real system. The process of determining the correctness of the model can be divided into 2 parts: Verification and Validation

2.3.7.1 Model Verification

Verification is the process of determining that a model performs as intended. Unintentional errors in the logic of the model should be isolated and removed as much as possible in a process of verification, called debugging. Verification is conducted in order to show that all parts of the model work both independently and together. It is a destructive process rather than a constructive one, Pegden (1995).

The followings are some guidelines that may be used to facilitate verification process:

- Establishing a doubting frame of mind. Verification is a process of examining a simulation model, with a strong intention to figure out and correct all errors. It is not just trying to show that the model works correctly as intended. A simulation model may operate properly for a given set of inputs, but fail under a new set of data. This is because the first set of data does not expose any error in the model. Therefore, a successful running is not a guarantee that the model is free of errors. Verification must be done by identifying and correcting errors, not by showing situation in which the model operate properly.
- Incorporating outside doubters. The outside doubters should be involved whenever possible. These people have no bias and wants to expose any error than the people who construct a model does. It is a fact that the model builder may not see an error or weak point in the task created by himself. The outside doubters facilitate this problem because the task will be examined from other points of view, not from the point that the model builder see it everyday. These outside doubters should not directly involve in phases of design and construction but they should take responsible for detecting

and isolating errors. Any error found should be then solved by the people who directly design and construct the model.

- Conducting model and experiment walkthroughs. Walkthroughs means going through the model block by block or manually simulating the movement of a small number of entities through the block diagram by a group of people. This group should consist of the people who develop the model and the outside people who are familiar with the system. However, this approach must be carefully applied in that any comment must be directed toward the model not toward the modeler.
- Performing test run. A test case would be used to examine the model. This case must be effectively reveal errors of logic in the model. It should consist operating conditions that extremely stress the interaction within the model by using extreme parameter setting.
- Using animation as a verification aid. Animation efficiently present dynamically movement of entities caused by interaction occurring within the simulation simultaneously. However, a high detailed animation is not required for a verification purpose. Only a rough appearance is sufficient for debugging.
- Correcting errors. When errors are detected, correcting them immediately without fully understand causes of errors may lead to disaster. Careful use of reason and logic must be aware by everyone. Once an error is removed, it is necessary to test the model again that the problem is totally removed. Moreover, correcting one error may lead additional errors

elsewhere in the model. Examining an effect of correcting one error should be then aware of.

All the details discussed are, however, just a tool that facilitate verification. Reasoning and skills of model developers are still required.

2.3.7.2 Model Validation

Validation is a process of examining that the model sufficiently mimics the real system. It is not judging whether or not the model is valid or invalid. Rather, it is a process of developing an acceptable level of confidence that the inferences drawn from the performance of the model are correct and apply to the real system. Validation starts from the phase of designing, constructing through a phase of using the model to ensure that the behavior of the model is close enough to that of the real system in terms of the purpose intended in building the model.

Pegden (1995) suggested that a group of people who should conduct a validation process should consist of a model builder, a technical evaluator, and an ultimate user. A model builder takes responsible for the confidence-building test. The technical evaluator may review the information and technical data provided by the model builder. Lastly, the ultimate user must agree and understand all the processes of validation as a decision- maker. Generally, the ultimate user should be an expert in other field who has little background of the model profile.

Validation may occur in 3 main circumstances: the real system exists and can be compared, the real system exists but cannot be compared since it may cause severe damage, and in the circumstance that the real system does not exit. In the first case, the behavior of the model can be directly compared with the real system. For the second one, extrapolating from the known behavior may be conducted to complete validation. For the last case, it is a case that some new assumptions are proposed to see their effects. Therefore, a belief and trust in model are necessary to decide that the model is valid enough to provide indications of what will happen.

Anyway, it should be noted that there is no model that is true or valid in any absolute sense because the model is constructed for only some particular purposes.

In validation, there are some specific areas of concern as follows:

- Defining validity. In order to believe in validity, the following approaches might be applied.
    - Rationalism means that all the assumptions of the model are obviously true and need not to be proved. The model that is based on the obviously assumption should be obviously valid.
    - Empiricism means that every assumption and outcome must be empirically tested and validated.
    - Positive economics means that if the model can be clearly shown that it works, it can be assumed to be valid regardless of the understandability, truth, and

rationality of the assumptions and structures involved.

- Testing for reasonableness. Reasonableness of model's behavior include the following item:
    - Continuity. Small change in the input parameters should cause appropriate change in the output.
    - Consistency. The same runs of the model should generate similar result. A little difference can be accepted but not a big one.
    - Degeneracy. When a main feature of the model is removed or changed, the output should obviously reflect the result of that removal or change.
    - Absurd condition. Though absurd inputs are set into the model, it should not show the absurd output. The model should not create impossible output such as a negative weight of material. It is the way to test the model under an unreasonable way to detect any problem. A good model should yield an acceptable output though extreme and unlikely conditions are given.
- Testing model structure and data. There are some guidelines for this type of testing.
    - Face validity. This test can be done by asking persons who familiar with the real system. Involving with the real user in every simulation process makes validation much easier. Moreover, it can be done by a helping hand of animation where a behavior of the system is graphically displayed.

  - Parameters and relationships. The parameters and the relationship may be tested by a statistical method e.g. means, variance, goodness of fit, regression analysis, hypothesis testing, etc.
  - Structural and boundary of verification. It is necessary to ensure that the structure of the model does not contradict reality. All the relationships required for imitating the real system must be completely gathered.
  - Sensitivity analysis. A change in the model's output caused by a variation of the model's parameter must be examined whether or not it is acceptable.
- Testing model behavior. The behavior of the model must be compared with those of the real system. Statistical test such as Chi-Square test, Kolmogorov-Smirnov test, regression analysis, symptom anomaly, behavior prediction can be done to prove the model.

Though there are many guidelines facilitating both verification and validation. These two processes are never really finished. Rather, they should be conducted as long as the model is still used.

2.3.8 Planning and Analysis of Simulation Output

Generally known that a usual purpose of using computer simulation is to find a clue of some improvement for the system being simulated. Therefore, it is necessary that the output of the simulation should be carefully interpreted.

Difficulties of interpreting a simulation output are due to involving in stochastic elements of the model input.

According to Pidd (1998), inputs whose effects are being investigated are categorized into two groups as follows:

- Parameters that define the configuration of the system e.g. the number of clerks in banking simulation system.
- Random samples from the various probability distributions e.g. inter-arrival time of customers entering to the banking simulation system

In order to correctly interpret the simulation output, it is important to clearly distinguish between the effects of sampling variation and those of the system configurations. Therefore, planning and interpreting the simulation output is trying to make distinction and maintaining this separation.

2.3.8.1 Terminating and Non-Terminating System

Terminating system is a simulation system that has some natural events that terminates the operation of the system, for example, a bank which operates from 9 a.m. to 5 p.m. In a terminating system, a transient behavior which brings the system to its climax is interested. A data analysis must take account in a correction of these data. It is said that many self-terminating system has no steady state.

On the contrary, a system without such an event to terminate the system is a non-terminating system. A non-terminating system is concerned at the center on the long-run or steady state behavior of the system. Confidence limits is then used to examine these average value of outputs. Any initial bias must be removed before focusing on a steady-state analysis. Pidd (1998) said that if the probability of being in one of its is governed by a fixed probability function, then a simulation is in a steady state. In order to bring a simulated system into a steady state, controlling its starting conditions or using a warm-up period might be applied. However, identifying its starting conditions is sometimes ideal since it is hard to exactly identify those conditions. Hence, using a warm-up period may be more appropriate. An idea is to let the simulation which begins with unrealistic, effectively null, system condition, etc. run until some steady-state condition is believed to achieve. After that, collecting statistical data can begin.

However, classification like this is sometimes based on the judgement of the analyst especially for some systems that are sometimes between these two types. As an example, a factory that operates from 8 a.m. and ends at 5 p.m., in the first point of view, this system can be viewed as terminating system since there is a natural event (clock reaches 5 p.m.) closes down the operation of the working line. However, from another point of view, this system can be regarded as a non-terminating system because a working line will be continue at 8 a.m. on the next day using the same line which was left on the previous day.

So, the analyst must consider first whether the analysis is to focus on the steady state or on transient effects in order to correctly plan a simulation experiment and analyze their outputs.

2.3.9 Application of Simulation

Simulation is now very popular among various types of research study, Pegden (1995). Almost all types of system can be simulated. It can be exploited in many working field such as computer system, manufacturing business, government, ecology and environment, society and behavior, bio-science, material handling systems, inventory control systems, transportation alternatives, etc.

The followings are examples of simulation application in some of those fields:

Simulation is applied with an inventory system of the Butler Electrical Supply Company, an electrical product supplier. Simulation is applied to figure out a suitable quantity of inventory that generates the lowest holding cost.

The American Red Cross uses a simulation model to study a behavior of the waiting line at the bloodmobile bus. It is used to find an appropriate operation process which can reduce the time that a blood donor has to spend in awaiting line. The waiting line and also the waiting time should be reduced as much as possible to improve a satisfaction of the blood donor. The GPSS computer simulation language was used to model the waiting line at the bloodmobile. After that, set up procedure, staff allocation, work rule, etc. were varied to see an effect on the waiting line.

At Mexico's Valpac Truck Company, the selection of manufacturing configurations and the design of new plant is guided by a simulation model. SIMNET II was used to model the manufacturing system. When the model is applied to a plant that was producing 20 trucks per day, the simulation model accurately predicted production at 19.8 trucks per day.

2.3.10 Advantage and Disadvantage of Simulation

According to Kelton (1998), simulation has been consistently reported as the most popular operation research tool. However, like other approaches, simulation has both advantages and disadvantages at the same time.

2.3.10.1 Advantage of Simulation

Simulation becomes more popular because of greater performance of computer hardware making it more cost effective to be used. Simulation generates many advantages over other operation research tool as follows:

- Simulation can describe complex system without simplifying assumptions or approximations which are required by other mathematical models. Simulation requires fewer simplifying assumptions and thereby it can capture more of the true characteristics of the real system.
- Simulation allows an experiment of the real system. New policies, operating procedures, new hardware designs, physical layouts may be tested before real implementation without disrupting ongoing operation. Changing assumptions or operating policies in the simulation model can predict how the changes will affect the operation of the real system. Hypothesis about how or why certain event occurs can be tested for feasibility. New situation, about which we have limited

knowledge and experience, can be manipulated in order to prepare for theoretical future events.

- Simulation has more credibility because its behavior has been compared to that of the real system. It also can be used to study the real system. Variables within the model are examined their importance and how they interact. It provides understanding how the system really operates as opposed to how the people think it operates. Causes of problems occur in the system can be identified using simulation.
- Time can be controlled by using simulation. Time can be compressed or expended according to the requirement of the user. It facilitates speeding up or slowing down a phenomenon for study.

2.3.10.2 Disadvantage of Simulation

Though simulation has many advantages, it could generate some disadvantages.

- Simulation requires the expertise to develop a simulation model and translating the model into computer language. Model building requires specialized training. The quality of the analysis depends on the quality of the model and the skill of the modeler.
- For a complex system, the process of developing, verifying, and validating a simulation model is a time-consuming and costly activity.
- Simulation cannot generate an optimal solution. It is a tool for the analysis of the system under a set of conditions. It is a run

process rather than a solving process. It cannot generate an optimal solution on its own as analytical models can. Anyway, there is an exception for a simulation model that is used to find the optimum values for a set of control variables under a given set of inputs.

- Simulation results may difficult to interpret because the model just tries to capture the randomness of the real system. Sometimes, it is hard to judge whether an observation made during a run is caused by a significant relationship in the system or by the randomness built into the model. Moreover, it is hard to determine how long is "long enough" to let the model run to get a reliable result. This interpretation depends on the experience of the user.
- Though simulation reduces many of over-simplifying assumptions, some are still left. These over-simplifying assumption results in invalid representation of the system. Hence, each simulation result is just an approximation of how the real system will operate. However, an approximate answer of the right problem is better than an exact answer of the wrong problem, Kelton (1998).

2.3.11 Steps of Simulation

In this section, various ideas about how the simulation study should be conducted will be provided to see a similarity and a difference among these approaches. Finally, the common steps of conducting the simulation study will be concluded and used as a guideline in doing the study in this thesis.

According to Pegden et. al. (1995), in order to gain the maximum profit from the simulation, the user must merge good problem-solving techniques with good software engineering practice. In simulation study, it should consist of the following steps:

1. Problem Definition. The goals of the study must be clearly defined.
2. Project Planning. The objective of this phase is to ensure that the resources required is sufficient e.g. personnel, management support, computer hardware, software, etc.
3. System Definition. Boundaries and restrictions to be used in defining the system must be determined.
4. Conceptual Model Formulation. In this phase, a preliminary model is developed to define the components, descriptive variables, and interactions that constitute the system.
5. Preliminary Experimental Design. The measures of effectiveness to be used, the factors to be varied, and the level of those factors to be investigated, etc. are identified.
6. Input Data Preparation. The input data required by the model is identified and collected.
7. Model Translation. The required model is created with appropriated simulation language.
8. Verification and Validation. The created model must be examined whether it operates the way the analyst intended and the output of the model is believable and representative of the output of the real system.
9. Final Experimental Design. The experiment must be designed in order to receive the desired information.
10. Experimentation. In this phase, the simulation is executed to generate the desired data and to perform a sensitivity analysis.

11. Analysis and Interpretation. The output from the simulation model is interpreted to provide the solution.
12. Implementation and Documentation. The simulation result is then implemented and also documented in the appropriated form.

It is said that the longer you wait to start Step 7, the faster you will complete the model and the project. “40-20-40” rule can be applied with these steps of simulation study. 40 percent of the effort and time in a project should be assigned to Step1 though 6, 20 percent to Step 7, and the remaining 40 percent to Step 8 through 12.

Identified by May (1990), the steps of doing simulation may be presented in a form of a flowchart as shown in figure 2.5.

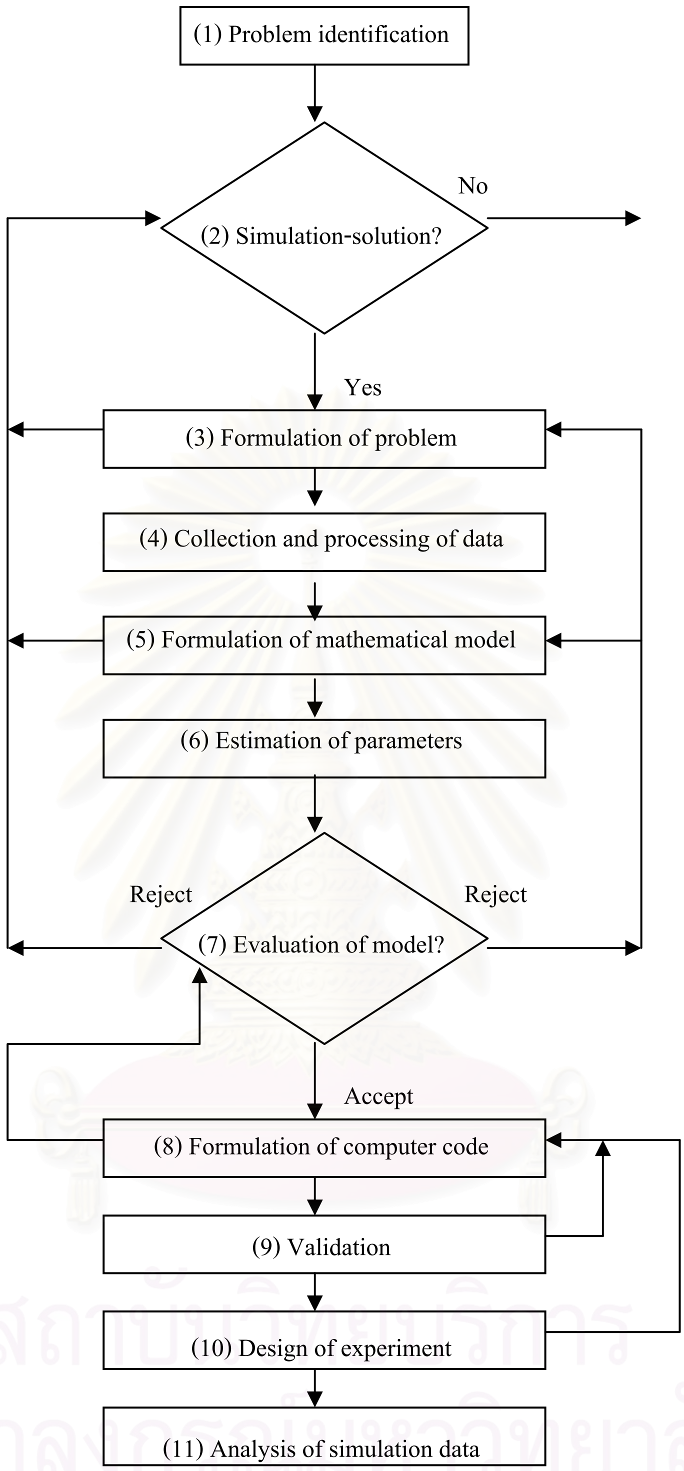

Figure 2.5: Flowchart of Procedural Element

Source: May, A.D., 1990, Traffic Flow Fundamentals, Prentice-Hall, Inc., New Jersey, USA., page 381

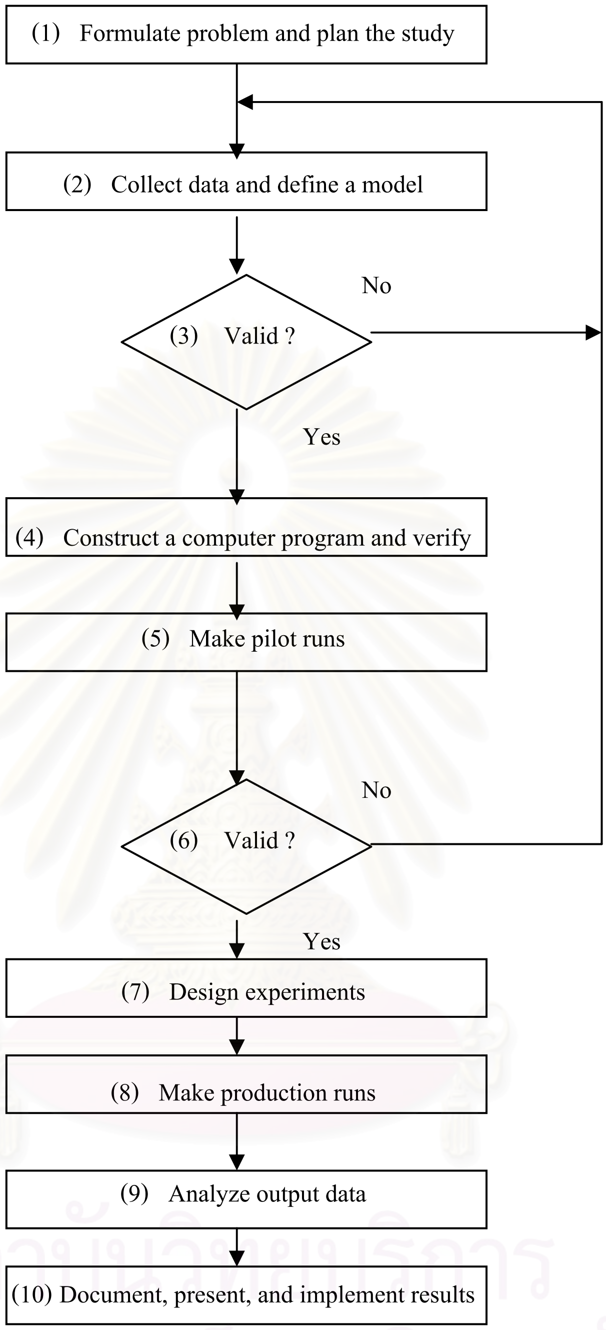

Figure 2.6: Steps in a Simulation Study

Source: Law A.M. and Kelton W.D., 1991, Simulation Modeling & Analysis, McGraw-Hill, Inc., USA., page 107

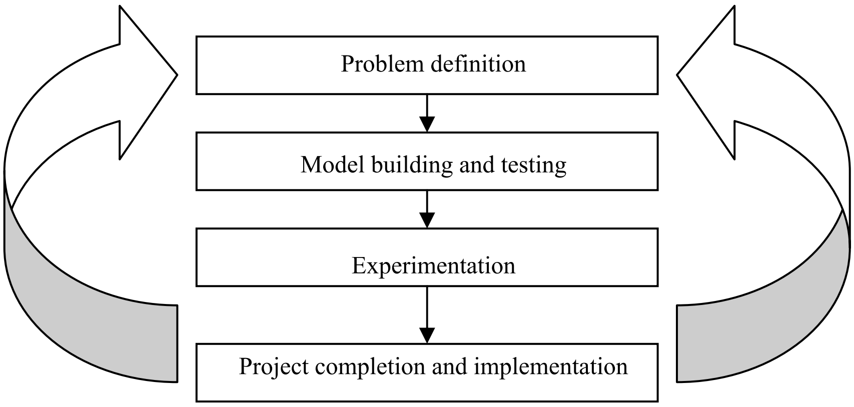

Figure 2.7: Simulation Project: An Overview

Source: Robinson, S., 1994, Successful Simulation, McGraw-Hill Book Company, Europe, Berkshire, England, page 30

From the four sets of simulation procedure proposed by various experts, the common steps among these sets can be summarized as follows:

1. Define the problem and set objective
2. Identify experiment factor
3. Determine the scope and level of simulation model
4. Collect and analyze the data
5. Build the based line model
6. Validate the model
7. Perform experiment
8. Obtain and analyze the results

These common steps will be used in conducting a simulation study in this thesis.

2.4 Physical Distribution Theory

2.4.1 James, Nicholas, and Robert

Logistics provided the most fruitful area for potential improvement of industrial and commercial activity, in terms of both the quality and the cost of its inputs. Logistics is the movement and handling of goods from the point of production to the point of consumption or use, defined by the American Marketing Association (AMA). Logistic as a function of the business enterprise, devotes primary attention to the movement and storage of products and supplies and is concerned only incidentally with the movement of people. In terms of business, logistics refers to the management of all activities which facilitate product movement and the coordination of supply and demand in the creation of time and place utility in goods. Logistic is made up of two related activities, physical supply and physical distribution. Each of them involves in management control and demand-supply coordination.

There are two types of facilities utilized by a logistic system, those for the storage and handling of product and those for the transmission processing, and storage of logistics information. The product support category includes two types of facilities: warehousing facilities and transferring facilities. They are used to finish the movement control function. The logistics information support category includes two types of facilities: communication facilities and data processing facilities. They are primary utilized in support the demand-supply coordination.

For the transportation mode, there are five basic categories: rail, highway, water, pipeline, and air. Trucks are considered to be less capable than rail carrier because of equipment limitations and the limitations of highway regulations governing the loaded weight and movement of trucks.

Information is a trigger for subsequent flow of physical material in a logistic system. It is used for planning, operating, and controlling the overall logistic system. The basis for logistics system planning can vary from old data to forecasts of future needs.

2.4.2 Ronald

The Council of logistics Management (CLM) defines "Logistics" as the process of planning, implementing, and controlling the efficient, cost-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 requirement.

Customer service standards set the level of output and degree of readiness to which the logistics system must respond. Logistics costs increase in proportion to the level of customer service provided. Setting very high service requirements makes logistics costs to exceedingly high levels. Transportation and inventories are the primary cost-absorbing logistics activities. It will approximately represent one-half to two-thirds of the total logistics costs. The transportation adds "place" value to products and services, whereas inventories add "time" value.

The logistician needs the short-term forecasts that assist in inventory control, shipment scheduling, warehouse load planning, etc. In general, complexity in forecasting models does not increase predictive accuracy. The exponential smoothing, classic time series decomposition, and multiple regression analysis are popular for this purpose.

Transportation usually represents the most important single element in logistics costs for most firms. The logistician needs a good understanding of transportation matters. The bulk of the freight movement is handled by the five basic modes of transportation: rail, truck, water, pipe, and air. The relative importance of each transportation mode and the changes that are occurring in their relative importance are partially explained by the composition of the freight hauled and the inherent advantages of the mode.

Rail and truck compete over essentially the same routes for much of the same freight. Trucking has been an effective competitor since 1929. Determined by the cost-service trade-off, rail, with lower rates and slightly lower level of performance as compared with truck, has concentrated in the lower value-weight and lower value-per-cube products.

2.4.3 John

Increasingly, proactive organizations are recognizing that logistics is uniquely placed within the organization to manage the interrelationship of all factors which affect the flow of both information and goods necessary to fill orders. This flow begins when the customer decides to place an order and ends when the order is fulfilled and money is collected. In order to succeed in today's environment, the organization must adopt a discipline and systematic approach to market, create carefully considered priorities, allocate resources in the strictest possible manner and make often difficult trade-off decisions. Modern logistics concept is that the organization must find innovative ways to improve profits, to increase market share, to improve cash flow, to open new territories, and to introduce new products.

The choice of the transport mode is a fundamental part of distribution management which should be analyzed carefully because it will impact on a company's operational efficiency. The nature of the transport services operated by each firm will vary considerably depending upon such factors as the nature of the product, the size of order, the service level required by the customer and the alternative transport methods available. Failure to identify the most appropriate transport method will lead to either incurring higher costs than are necessary and/or to providing a lower customer service potentially possible. Selecting the most appropriate transport mode can be done by using judgement, cost trade-off, and distribution model.

2.4.4 Roger

The National Council of Physical Distribution Management (NCPDM) defines physical distribution as the broad range of activities concerned with efficient movement of finished products from the end of the production line to the consumers and in some cases includes the movement of raw materials from the source of supply to the beginning of the production line. NCPDM also states that the physical distribution management (PDM) included freight transportation, warehousing, materials handling, protective packaging, inventory control, plant and warehouse site selection, order processing, market forecasting and customer service. Physical distribution is concerned with demand satisfaction. In other words, it is responsible for making the product available when and where the customer wants it.

The choice of the transport mode in a physical distribution system depends on a number of factors related to cost and performance. It is not choosing the mode with the lowest freight rates and expecting this one to result in the lowest total distribution cost. Transport cost has to be related to costs in other points of the distribution system. Product characteristics, length of haul, freight rates, and service and reliability must be concerned in selecting the appropriate transport mode.

In order to plan the number of vehicles required, alternative distribution patterns and a considered evaluation of the customer service level that the company wishes to provide must be carefully examined. The company can acquire the vehicles by outright purchase, hire purchase, or leasing. The choice depends on which method minimizes the impact on the company finance.

There are five main transport modes: rail, road, water, air, and pipeline. Each of them has operating characteristics that differ from each other according to given situation. It is the distribution manager’s job to choose the mode with the most desirable attributes given the prevailing external conditions and circumstances. The transport service that will best fit the company’s overall distribution strategy must be figured out.

All the contents discussed above are theoretical details that might be applied in solving problems occur in the LPG distribution system. In the next chapter, details of the Existing LPG distribution system is deeply explained in order to generate an idea how these theoretical details can be applied with the real system.

CHAPTER 3

EXISTING LPG DISTRIBUTION SYSTEM FOR LPG DEPOTS IN THE NORTH AND NORTHEAST OF PTT

In Chapter 1, primary information about LPG distribution system has already been addressed. In this chapter, those information is going to be further discussed in more details by focusing on only rail and truck transportation to depots in the North and Northeast in order to create a better understanding about the problems.

3.1 Working Flow of the Involved Departments

The present LPG distribution to depots in the North and Northeast of PTT is involved in various departments. The following steps are working flow of the system.

1. LPG Sales Department. This department will summarize all the LPG demand from the customers and then inform the customers' demand of each LPG depot (KKN, LMP, and NSW) to the Supply Planning and Operation Department in form of 12 month-rolling-basis plan which means the LPG volume of the next month will be informed together with those of the next 11 months. However, only the LPG volume of the next month is confirmed while those of the rest 11 months are just a forecasting volume. The total present demand of these three depots is around 37,000-40,000 tons per month depending on the seasonal factor.

2. The Supply Planning and Operation Department will procure LPG volume from the supply sources. There are only two supply sources involved in this case, GSP LKB and GSP Rayong. Firstly, GSP LKB will commit the LPG volume that is going to be produced in the next month, normally about 9,000 tons per month. The rest volume of LPG will be procured from GSP Rayong. At this stage, both of the supply

sources will make a commitment to produce the required volume of the next month according to PTT's requirement.

3. The Supply Planning and Operation Department will inform the Depot Storage Management Division the LPG receiving plan which consists of the LPG volume that they have already committed with each supply source and also the customers' demand of each depot as illustrated in table 3.1, on page 59.

4. The Depot Storage Management Division will use all the information received from the Supply Planning and Operation Department to set the monthly LPG distribution plan for each regional depot. This plan consists of mode of transportation (only rail and truck in this study), supply source, LPG volume planned to be transported in each trip from each supply source, destination depot, etc. as shown in table 3.2, on page 60.

5. The regional depots will receive LPG according to the distribution plan. After that the LPG depot will sell LPG to the customers ending up the LPG supply chain system.

All the steps explained above are summarized as shown in figure 3.1, on the next page.

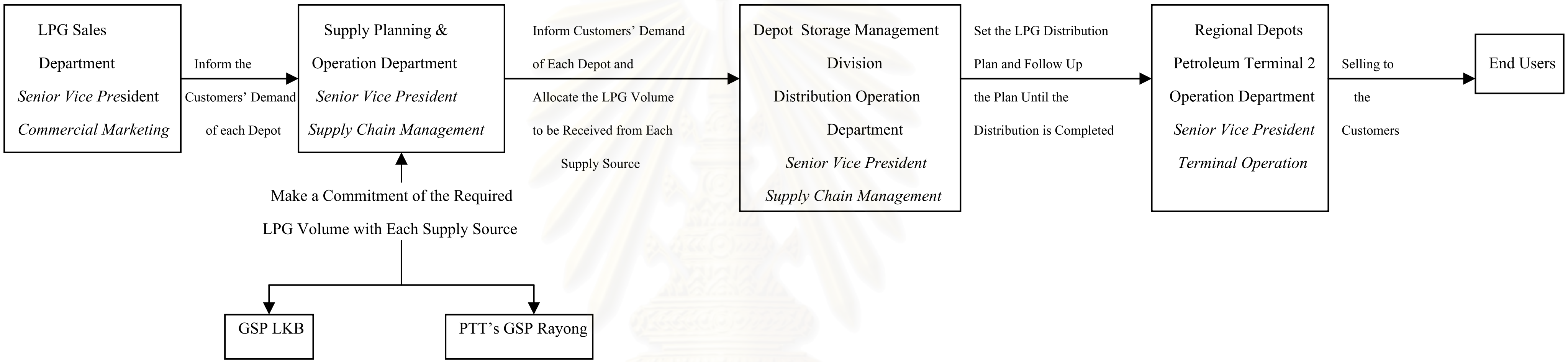

Figure 3.1: Working Flow of the Involved Departments

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President, Supply Chain Management, PTT

LPG Distribution Plan as of March, 2000

Unit: k.tons

Depot	Supply								Total	Distributor		Demand			Total
	BCP	TORC	RRC	SPRC	GSP Rayong, ATC, and BST	GSP KNM	GSP LKB	Import	Supply	BRP	MT	MKT.	S/S	Export	Demand
BCK	1.5	4.3	5.4	4.6		1.0			16.8		5.9	22.4	0.3		22.7
BRP					34.5				34.5			4.1	0.2		4.3
NSW									0.0	10.6		5.3	5.3		10.6
LMP							9.1		9.1	3.5		5.8	6.8		12.6
KKN									0.0	16.2		7.1	9.1		16.2
SRT						7.5			7.5			4.0	3.5		7.5
SKL						8.3			8.3		1.1	2.9	4.9	1.6	9.4
MT					19.2				19.2			0.0	12.2		12.2
Total	1.5	4.3	5.4	4.6	53.7	16.8	9.1	0.0	95.4	30.3	7.0	51.6	42.3	1.6	95.5

APPROVED BY : .... DATE : ....

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Table 3.1: LPG Receiving Plan as of March, 2000

Source: Supply Planning and Operation Operation Department, Senior Vice President Supply Chain Management, PTT

LPG DISTRIBUTION PLAN AS OF MARCH'2000

KONKHAEN

Date	Open Inventory Plan	Open Inventory Actual	Demand Plan	Demand Actual S/S	Demand Actual Total	Supply (Rail) Plan	Supply (Rail) Actual
1	1200		600			458	
2	1058		600			458	
3	916		600			458	
4	774		600			916	
5	1090		0			458	
6	1548		600			458	
7	1406		600			458	
8	1264		600			916	
9	1580		600			458	
10	1438		600			458	
11	1296		600			458	
12	1154		0			458	
13	1612		600			458	
14	1470		600			458	
15	1328		600			458	
16	1186		600			916	
17	1502		600			458	
18	1360		600			458	
19	1218		0			458	
20	1676		600			458	
21	1534		600			458	
22	1392		600			916	
23	1708		600			458	
24	1566		600			458	
25	1424		600			458	
26	1282		0			458	
27	1740		600			458	
28	1598		600			458	
29	1456		600			458	
30	1314		600			458	
31	1172		600			916	
1	1488	Total	16200	0	0	16488	0

LAMPANG

Date	Open Inventory Plan	Open Inventory Actual	Demand Plan	Demand Actual S/S	Demand Actual Total	Supply Plan Rail	Supply Plan LKB	Supply Plan BRP	Supply Plan Total	Supply Actual Rail	Supply Actual LKB	Supply Actual BRP
1	1300		467				295	80	375			
2	1208		467				295	80	375			
3	1116		467				295	80	375			
4	1024		467				295	80	375			
5	932		0				295	80	375			
6	1307		467				295	80	375			
7	1215		467				295	80	375			
8	1123		467				295	80	375			
9	1031		467				295	80	375			
10	939		467			458	295	80	833			
11	1305		467				295	80	375			
12	1213		0				295	80	375			
13	1588		467				295	80	375			
14	1496		467				295	80	375			
15	1404		467				295	80	375			
16	1312		467				295	80	375			
17	1220		467				295	80	375			
18	1128		467				295	80	375			
19	1036		0				295	80	375			
20	1411		467				295	80	375			
21	1319		467				295	80	375			
22	1227		467				295	80	375			
23	1135		467				295	80	375			
24	1043		467			458	295	80	833			
25	1409		467				295	80	375			
26	1317		0				295	80	375			
27	1692		467				295	80	375			
28	1600		467				295	80	375			
29	1508		467				295	80	375			
30	1416		467				295	80	375			
31	1324		467				295	80	375			
1	1232	Total	12609	0	0	916	9145	2480	12541	0	0	0

NAKORNSAWAN

Date	Open Inventory Plan	Open Inventory Actual	Demand Plan	Demand Actual S/S	Demand Actual Total	Supply Plan Rail	Supply Plan LKB	Supply Plan BRP	Supply Plan Total	Supply Actual Rail	Supply Actual LKB	Supply Actual BRP
1	1000		393			510			510			
2	1117		393			510			510			
3	1234		393			510			510			
4	1351		393						0			
5	958		0			510			510			
6	1468		393			510			510			
7	1585		393			510			510			
8	1702		393						0			
9	1309		393			510			510			
10	1426		393						0			
11	1033		393			510			510			
12	1150		0						0			
13	1150		393			510			510			
14	1267		393			510			510			
15	1384		393			510			510			
16	1501		393						0			
17	1108		393			510			510			
18	1225		393			510			510			
19	1342		0						0			
20	1342		393			510			510			
21	1459		393			510			510			
22	1576		393						0			
23	1183		393			510			510			
24	1300		393						0			
25	907		393			510			510			
26	1024		0						0			
27	1024		393			510			510			
28	1141		393			510			510			
29	1258		393			510			510			
30	1375		393			510			510			
31	1492		393						0			
1	1099	Total	10611	0	0	10710	0	0	10710	0	10710	0

Rev.6 (100102) PREPARED BY : ________ DATE : ________ 1st APPROVED BY : ________ DATE : ________ 2nd APPROVED BY : ________ DATE : ________ TQP-UIC-001-001(1/3)

Table 3.2: LPG Distribution Plan as of March, 2000 for KKN, LMP, and NSW
Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

3.2 How the Depot Storage Management Division Works

From the working flow discussed in the previous part, the main activity that will be further analyzed in this thesis is the working activity of the Depot Storage Management Division. In order to easily understand the way the scheduler of the Depot Storage Management Division works, the details of this topic are organized into 4 parts, working constraints concerned in setting LPG distribution plan, decision logic used in setting LPG distribution plan, methods of setting LPG distribution plan, and daily operation.

3.2.1 Working Constraints Concerned in Setting LPG Distribution Plan

In setting LPG distribution plan, there are some major constraints that must be concerned as follows:

1. Committed volume of each supply source. For a supply source that does not belong to PTT, in this case GSP LKB, LPG must be received from GSP LKB according to the allocated volume committed by the Supply Planning and Operation Department. Otherwise, PTT has to pay for a penalty. For GSP LKB, the actual volume received in each month must be within the range of the committed volume $\pm$ 5%. For example, if the committed volume is equal to 9,100 tons per month, the actual volume that PTT can receive from GSP LKB may be varied within the range of $0.95 \times 9,100 = 8,645$ to $1.05 \times 9,100 = 9,555$ tons.

2. Operating schedule constraints. Although, all the operators can operate 24 hours a day, in normal case the 24 hour-operation should not occur since the operating cost will significantly increase. Hence, the scheduler must try to make every operation occurs within the normal working hours.

3. Inventory level. An inventory level of each regional depot must be compatible with the management policy that is about 1 or 2 selling-days depending on the characteristics of each regional depot. About the maximum capacity of the sphere, there are 2 spheres at each depot, KKN, LMP, and NSW. Each sphere has the maximum capacity of 1,000 tons. However, for a safety reason, the maximum working capacity is equal to 85% of the maximum capacity = $0.85 \times 1{,}000 = 850$ tons for each sphere. Therefore, the total working capacity is equal to 1,700 tons for each regional depot. For BRP, there are 3 1,000-ton-spheres with a total working capacity of 2,550 tons. Lastly, GSP LKB has approximately 1,500 tons of a working capacity of the spheres.

4. Transportation Equipment. For rail, PTT has to invest its own bogies which cost approximately 6,111,000 baht per bogie or about 109,998,000 baht per rail (18 bogies). Moreover, PTT has to take care of all the maintenance activities of the bogies. Obviously, it is very high investment in buying new bogies. On the contrary, for truck, PTT does not have its own trucks. Every truck involved in this case belongs to the truck contractor. Therefore, PTT pays only the transportation freight to the truck contractor and involves in neither buying truck nor maintenance responsibility. It is very low investment compared with buying new bogies. Consequently, the management policy for these two types of transporters is different. At this moment, PTT will freeze the number of bogies used in the existing fleet and will exploit truck transportation to fulfill the rest of the LPG demand that cannot be coped by rail transportation. Now, there are 90 bogies used in the system. The maximum number of rail that can be sent from BRP is 2 rails per day because of the limited number of bogies and a locomotive engine provided by the State Railway of Thailand. For truck, now there are about 45 trucks. This number of trucks can work in both 2 fleet, GSP LKB fleet and BRP fleet. However, according to the management policy, the number of truck used in the system

can be increased by finding new truck contractors or by expanding the capacity of the existing contractors.

5. Transportation turnaround time. In setting LPG distribution plan, a transportation turnaround time must be concerned in order to efficiently utilize the existing resources. For rail to KKN and NSW, a turnaround time is 2 days while for LMP, it takes 4 days (include the waiting time for a locomotive engine). Truck from BRP to KKN and LMP takes 2 day-turnaround time while truck from BRP to NSW takes only 1 day. Truck from GSP LKB to all the three depots, KKN, LMP, and NSW approximately takes 1 day for a turnaround time.

6. Size of transportation equipment. Rail to KKN and LMP consists of 18 bogies per rail while rail to NSW consists of 20 bogies per rail. This difference is due to a geographical characteristic of each route. For example, rail sent to KKN and LMP must climb up the mountain. On the contrary, rail sent to NSW just travels on a plain route. A capacity of each bogy is 25.5 tons. Thus, rail to KKN and LMP has a capacity of $18 \times 25.5 = 458$ tons per rail and $20 \times 25.5 = 510$ tons per rail for rail to NSW. For truck, each truck has a capacity of 16 tons.

7. Freight. A scheduler must try to set the plan that generates the minimum transportation cost. Details of this issue are going to be discussed in the next part, 3.2.2 Present Decision Logic Used in Setting the LPG Distribution Plan.

8. Others. Besides all those major constraints, there are also some other miscellaneous constraints that a scheduler must concern about. For example, a rail or truck failure may make a transportation deviates from the schedule. In order to absorb this deviation, a scheduler must exploit his working experience to provide some idle allowance in the LPG distribution plan in order to create a chance to bring the situation back to normal if any unexpected situation occurs.

3.2.2 Present Decision Logic Used in Setting LPG Distribution Plan

As previously discussed, this stage of planning is done according to a working experience of the scheduler. It is hard to explain in term of a logical explanation. However, at the present, a transportation freight is another major factor affecting a decision making of the scheduler. Truck freight varies according to the price of High-Speed-Diesel Oil while rail freight is fixed at a constant rate. In this thesis, both truck freight and rail freight are assumed to be fixed throughout the study. They will not increase when the time passes each year. The following tables are truck and rail freight from each supply source to various destination depots.

Unit: baht/ton

Range of High-Speed-Diesel Price (baht/liter)	**Destination**		
	Konkhaen	**Lampang**	**Nakornsawan**
8.51-9.00	923.45	809.29	404.12
9.01-9.50	941.91	825.47	412.20
9.51-10.00	959.72	841.08	419.99
10.01-10.50	976.94	856.17	427.52
10.51-11.00	993.61	870.78	434.82
11.01-11.50	1,009.78	884.95	441.90
11.51-12.00	1,025.48	898.71	448.77

Table 3.3: Truck Freight from GSP LKB to KKN, LMP and NSW

Source: Distribution Planning Department, Senior Vice President Supply Chain Management, PTT

Unit: baht/ton

Range of High-Speed-Diesel Price (baht/liter)	**Destination**		
	Konkhaen	**Lampang**	**Nakornsawan**
8.51-9.00	1,290.00	1,850.00	966.00
9.01-9.50	1,316.00	1,887.00	986.00
9.51-10.00	1,341.00	1,923.00	1,004.00
10.01-10.50	1,365.00	1,957.00	1,022.00
10.51-11.00	1,389.00	1,991.00	1,040.00
11.01-11.50	1,411.00	2,023.00	1,057.00
11.51-12.00	1,433.00	2,054.00	1,073.00

Table 3.4: Truck Freight from BRP to KKN, LMP and NSW

Source: Distribution Planning Department, Senior Vice President Supply Chain Management, PTT

Unit: baht/ton

Supply Source	**Destination**		
	Konkhaen	**Lampang**	**Nakornsawan**
BRP	506.00	702.00	382.00

Table 3.5: Rail Freight from BRP to KKN, LMP and NSW

Source: Distribution Planning Department, Senior Vice President Supply Chain Management, PTT

From the three tables illustrated above, it is clear that the rail freight is comparatively cheaper than the truck freight. The followings are priority used in setting the LPG distribution plan.

1. The scheduler will try to maximize using rail first. In order to do that, rail should be transported in the shortest route. Consequently, rail will be sent to KKN and NSW that have a turnaround time of 2 days first. It will not be sent to LMP because in this case it will take 4 days for a turnaround time and this will reduce a rate of rail utilization.

2. For GSP LKB, LPG will be sent to LMP first in order to compensate the LPG volume that cannot be sent by rail.

3. Lastly, if the LPG volume sent from BRP by rail and from GSP LKB by truck is not sufficient to serve the demand of these three depots, truck will be sent from BRP as the last alternative to fulfill the rest of the demand.

However, this decision logic has not been proved by a scientific method. It is just a concept taught from generation to generation of the scheduler.

3.2.3 Methods of Setting LPG Distribution Plan

When the Supply Planning and Operation Department informs the Depot Storage Management Division a monthly LPG receiving plan which consists of LPG demand of each depot and the LPG volume allocated at each supply source for each depot as shown in table 3.1, a scheduler of the Depot Storage Management Division will break this monthly plan into a daily plan by setting a daily operation for each depot. The LPG distribution plan set by the Depot Storage Management Division must be compatible with this plan.

In this thesis, only the LPG distribution plan for KKN, LMP, and NSW is concerned. As shown in table 3.2, the LPG distribution plan for these depots consists of an estimated opening inventory of each day, a daily demand, and a daily receiving LPG volume from each supply source.

For a better understanding of the planning procedure done by a scheduler of the Depot Storage Management Division, the LPG distribution plan of LMP as of March, 2000 is explained as a case study.

Firstly, a monthly demand of LMP is broken into a daily demand. The daily demand comes from the monthly LPG receiving plan informed by the Supply Planning and Operation Department divided by the number of days that LMP operates the selling activities in March, 2000. In March, 2000, LMP operates the selling activities in everyday except for Sunday. Therefore, the total selling days of LMP in March, 2000 is equal to 27 days. From the table 3.1, the monthly demand of LMP is 12,600 tons. Consequently, the daily demand of LMP can be calculated from 12,600/27 $\approx$ 467 tons per day.

When the daily demand is obtained, the responsibility of the scheduler is to set a receiving plan from the allocated supply source in order to sufficiently serve the daily demand. As illustrated in table 3.1, in March, 2000 LMP must receive LPG from GSP LKB 9,100 tons and from BRP 3,500 tons. The LPG from GSP LKB can be transported only by truck while for BRP, it can be transported by both truck and rail. The LPG distribution plan must be done by concerning all the involved constraints mentioned previously. In a real operation, the LPG distribution plan for KKN, LMP, and NSW must be done simultaneously because these three depots use the same fleet of transportation equipment. The final LPG distribution plan is a solution that must be practical to work with for every party involved.

By concerning all the constraints involved and using a decision logic as explained previously, as shown in table 3.2, LPG is sent from GSP LKB to LMP 295 tons per day, from BRP by rail 916 tons, on March 10 and March 24, 458 tons each, and from BRP by truck 80 tons per day. Totally, in the LPG distribution plan, LPG will be sent from GSP LKB 9,145 tons (The volume informed in the receiving plan is equal to 9,100 tons.) and from BRP 3,396 tons (The volume informed in the receiving plan is equal to 3,500 tons.) in March, 2000. The reasons why the volume in the LPG distribution plan slightly deviates from the LPG receiving plan of the Supply Planning and Operation Department is that the constraints about the size of transportation equipment and all other constraints must be concerned in setting plan. Therefore, the LPG volume identified in the LPG distribution plan of the Depot storage Management Division is just approximately equal to the volume informed by the Supply Planning and Operation Department because of these constraints involved.

Similarly, the LPG distribution plan for KKN and NSW is done in the same way. When the plan for these 3depots in completed, the Depot Storage Management will inform every party involved within the last week of each month. All the involved people will use this plan as a working schedule of the next month. For example, the Depot Storage Management Division will inform the LPG distribution plan as of March, 2000 within the last week of February, 2000.

3.2.4 Daily Operation

When the LPG distribution plan set by a scheduler of the Depot Storage Management Division is distributed to every party involved: operators at supply sources, transportation contractor, operators at destination depots, the State Railway of Thailand, etc. The operators at each area will start doing jobs under their responsibilities according to the plan. Events occur in actual daily operation may be roughly illustrated as follows:

- Operators at supply sources, BRP and GSP LKB (the loading site), start preparing the spheres to make them ready for loading operation by receiving LPG through a pipeline system from GSP Rayong and GSP LKB (the process unit) respectively.
- Operators at supply sources check for the quality of LPG to ensure that it meet the specification.
- Transporters, rail and/or truck, travel to the supply source.
- Operators at the supply sources start loading LPG from the spheres to transporters according to the LPG distribution plan.
- Transporters start travelling to the destination depots, KKN, LMP, and NSW.
- Operators at destination depots unloading LPG from transporters and send it to the spheres.
- Transporters travel back to their base sites.
- Operators at destination depots sell LPG kept in the spheres to customers.

This loop of activities is repeated in daily operation. In everyday, it is a responsibility of the scheduler who set this LPG distribution plan to follow up all of these daily operations in order to check whether everything is going well according to the plan. If there is anything deviates from the plan and the plan seems no longer suitable for the existing situation e.g. daily demand is greater than the expected volume, LPG transportation volume is less than the target because of an accident, etc., the scheduler must immediately review the plan in order to keep the situation back to normal as soon as possible.

3.3 Present Problem

From the discussed planning procedure, the main objective of the present way of setting the LPG distribution plan is to sufficiently serve the customers' demand while a transportation cost which is another important factor is not systematically concerned. The decision logic used in nowadays has not been approved whether or not it is correct. There is no guideline how much LPG should be transported by rail and how much by truck from BRP in order to minimize the transportation cost while all the other working constraints are also still fully met at the same time. Everything is based on an experience of the scheduler. The scheduler uses his common sense to set the most economical LPG distribution plan according to his thought.

Furthermore, from an experience of the scheduler, the existing amount of transportation equipment is quite fit with the existing demand. It means that if the demand is still growing with the present trend, the existing transportation equipment will no longer be able to cover this growing demand. Hence, the LPG distribution plan in the future should be proposed in advance in order to provide enough time in procuring the required transportation equipment to sufficiently serve the customers' demand. The forecasted demands of the next five years are illustrated in table 3.6 on the next page.

Moreover, the existing planning procedure cannot efficiently absorb some uncontrollable constraints e.g. rail or truck failure, accident, etc. These uncontrollable factors make the LPG distribution plan impractical when these things happen. Thus, if these factors are correctly included in the model used in setting the plan, the plan will be more practical with the real working situation.

Year 2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
KKN	16,400	14,900	15,700	16,000	16,300	16,000	17,200	17,500	17,100	16,800	17,100	18,000	199,000	16,583
LMP	13,300	11,900	12,600	12,500	12,400	12,400	13,700	14,100	13,100	13,300	14,000	14,500	157,800	13,150
NSW	11,000	9,900	10,300	9,900	10,100	10,100	10,800	11,300	11,300	11,000	11,300	11,500	128,500	10,708
Total	**40,700**	**36,700**	**38,600**	**38,400**	**38,800**	**38,500**	**41,700**	**42,900**	**41,500**	**41,100**	**42,400**	**44,000**	**485,300**	**40,442**

Year 2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
KKN	17,400	15,700	16,500	16,800	17,200	16,900	18,100	18,400	18,100	17,700	18,100	19,000	209,900	17,492
LMP	14,500	13,000	13,700	13,500	13,500	13,400	14,800	15,300	14,200	14,400	15,100	15,600	171,000	14,250
NSW	11,600	10,400	10,900	10,500	10,600	10,600	11,400	11,900	11,900	11,600	11,900	12,100	135,400	11,283
Total	**43,500**	**39,100**	**41,100**	**40,800**	**41,300**	**40,900**	**44,300**	**45,600**	**44,200**	**43,700**	**45,100**	**46,700**	**516,300**	**43,025**

Year 2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
KKN	18,300	16,600	17,400	17,700	18,100	17,800	19,000	19,400	19,000	18,600	19,000	19,900	220,800	18,400
LMP	15,600	14,000	14,800	14,500	14,500	14,500	15,900	16,400	15,300	15,500	16,200	16,800	184,000	15,333
NSW	12,200	11,000	11,400	11,000	11,200	11,200	11,900	12,500	12,500	12,100	12,500	12,700	142,200	11,850
Total	**46,100**	**41,600**	**43,600**	**43,200**	**43,800**	**43,500**	**46,800**	**48,300**	**46,800**	**46,200**	**47,700**	**49,400**	**547,000**	**45,583**

Year 2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
KKN	19,200	17,400	18,300	18,600	19,000	18,700	20,000	20,300	19,900	19,500	19,900	20,900	231,700	19,308
LMP	16,800	15,000	15,800	15,600	15,600	15,500	17,000	17,600	16,300	16,500	17,300	17,900	196,900	16,408
NSW	12,800	11,500	12,000	11,500	11,700	11,700	12,500	13,100	13,100	12,700	13,000	13,300	148,900	12,408
Total	**48,800**	**43,900**	**46,100**	**45,700**	**46,300**	**45,900**	**49,500**	**51,000**	**49,300**	**48,700**	**50,200**	**52,100**	**577,500**	**48,125**

Year 2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
KKN	20,200	18,300	19,200	19,500	19,900	19,600	20,900	21,300	20,900	20,400	20,800	21,800	242,800	20,233
LMP	17,900	16,000	16,900	16,600	16,600	16,500	18,200	18,700	17,400	17,600	18,400	19,100	209,900	17,492
NSW	13,400	12,100	12,600	12,100	12,300	12,300	13,100	13,700	13,700	13,300	13,600	13,900	156,100	13,008
Total	**51,500**	**46,400**	**48,700**	**48,200**	**48,800**	**48,400**	**52,200**	**53,700**	**52,000**	**51,300**	**52,800**	**54,800**	**608,800**	**50,733**

Table 3.6: LPG Demand of KKN, LMP, and NSW as of 2001-2005 (Unit: tons)

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

Unit: tons

Demand	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	% Growth
2,001	40,700	36,700	38,600	38,400	38,800	38,500	41,700	42,900	41,500	41,100	42,400	44,000	40,442	-
2,002	43,500	39,100	41,100	40,800	41,300	40,900	44,300	45,600	44,200	43,700	45,100	46,700	43,025	6.39
2,003	46,100	41,600	43,600	43,200	43,800	43,500	46,800	48,300	46,800	46,200	47,700	49,400	45,583	5.95
2,004	48,800	43,900	46,100	45,700	46,300	45,900	49,500	51,000	49,300	48,700	50,200	52,100	48,125	5.58
2,005	51,500	46,400	48,700	48,200	48,800	48,400	52,200	53,700	52,000	51,300	52,800	54,800	50,733	5.42

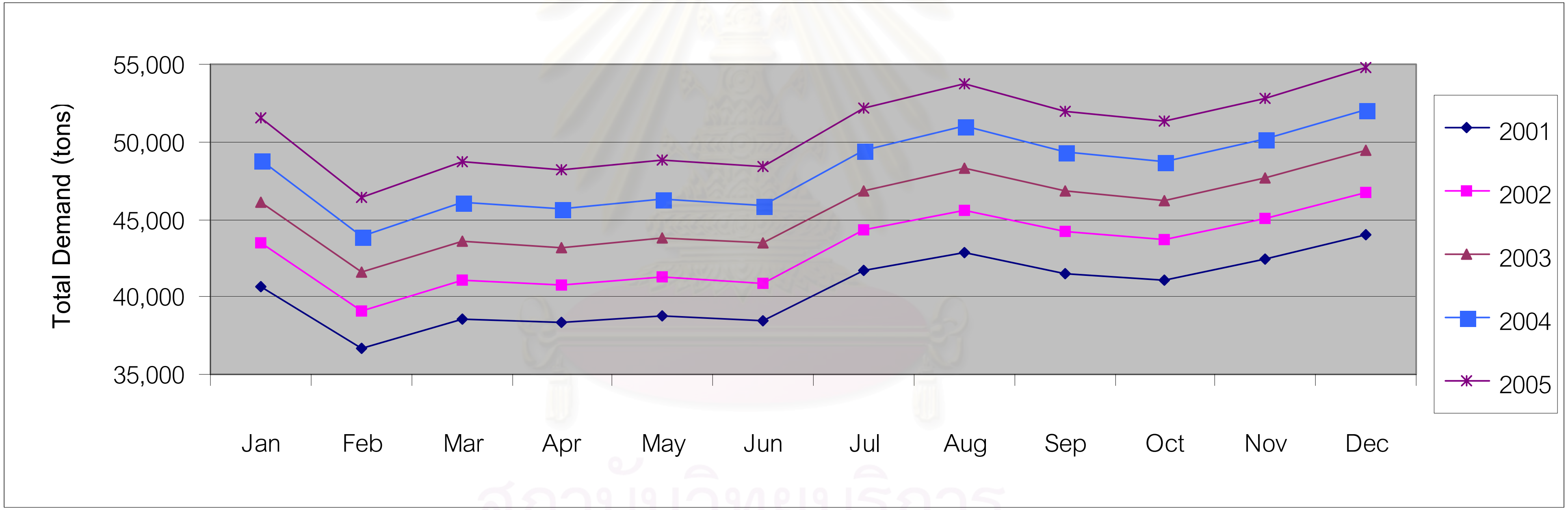

Figure 3.2: Growth of Total Monthly Demand as of 2001-2005

From figure 3.2, the customers' demand has a growth rate of approximately 5% to 6% in each year. Therefore, the new transporters must be added into the transportation system to sufficiently serve this growing demand.

Now, the LPG distribution system is clearly discussed in details. The existing problems occur in actual operation are also identified. Therefore, in the next chapter, the problems will be solved step by step by the proposed methodology.

CHAPTER 4

APPLYING LINEAR PROGRAMMING IN LPG DISTRIBUTION SYSTEM

All the work done in Chapter 1 through Chapter 3 is an attempt to provide all the details about the problem and also some involved theoretical issues. Now, a problem is clearly understood. Hence, solving problem is going to be started. Method of solving the problems can be divided into 2 phases. In the first phase, LP will be applied to figure out a deterministic solution of the LPG distribution system. After that, in the second phase, this deterministic solution obtained from the LP model will be put into the simulation model in order to verify whether or not it is practical for the real world case. The adjusted solution get from the simulation model will be proposed as a five-year-plan for the LPG distribution system.

Initially, LP is selected as a decision making tool to generate an initial solution of the LPG distribution problem. This idea is supported by Thomas et. al. (1993), LP is used to get approximate solutions to non linear problem since LP is generally much faster and can solve much larger problems than the nonlinear techniques do.

In this chapter, theory of LP discussed in Chapter 2 will be applied with the existing LPG distribution plan described in Chapter 3 step by step. A solution obtained from the LP model will be interpreted to achieve an initial idea of how the LPG distribution system should be. As previously discussed, if the management still want to keep the present policy, not to invest in rail, the total transportation cost must be significantly increased each year inevitably because the higher truck freight plays more important role. Therefore, in this thesis, other policies will be proposed compared with the present one in order to identify the most suitable policy for the next five years. Consequently, at first, the LP model will be run according to the present policy, no rail is added, in order to primarily evaluate its results. After that, the constraint that limits the rail transportation capability will be removed in order to figure out the exact number of rails that the system really requires in minimizing the total transportation cost. This number of rails that the system actually requires will be further exploited in a phase of simulation as a boundary to limit the scope of the experiment. Details of this issue will be deeply explained later on.

In addition, the result of the LP model as of March, 2000 will be compared with what actually happens in the operation plan of March, 2000 which is set by the existing logical concept of the scheduler in order to figure out whether or not the existing logic used in setting plan nowadays is suitable. Lastly, some interesting points noticed from the LP result will be proposed as a comment.

The LP model of the LPG distribution plan will be done according to the formulating steps of LP model discussed in Chapter 2 by using the case of March, 2000 as a case study as follows:

4.1 Understand the Problem

Nowadays, the problem is that there is no mathematical method applied in setting the LPG distribution plan. All details about the existing problem and the general profile of LPG distribution system have already been clearly explained in Chapter 1 and Chapter 3 respectively.

4.2 Identify the Decision Variable

Decision variables that are varied to find the optimum solution while the model being solved are LPG volume from each supply source to each destination depot by each type of vehicle.

As previously discussed, supply sources involved in this case are BRP and GSP LKB. Destination depots are KKN, LMP, and NSW. Truck and rail are used for transporting LPG from BRP to the three destination depots. For GSP LKB, only truck is used for doing that. Therefore, decision variables can be identified as follows:

x_1 = *LPG volume transported from BRP to KKN by rail, tons*

x_2 = *LPG volume transported from BRP to LMP by rail, tons*

x_3 = *LPG volume transported from BRP to NSW by rail, tons*

x_4 = *LPG volume transported from BRP to KKN by truck, tons*

x_5 = *LPG volume transported from BRP to LMP by truck, tons*

x_6 = *LPG volume transported from BRP to NSW by truck, tons*

x_7= *LPG volume transported from GSP LKB to KKN by truck, tons*

x_8= *LPG volume transported from GSP LKB to LMP by truck, tons*

x_9= *LPG volume transported from GSP LKB to NSW by truck, tons*

4.3 Choose a Numerical Measure of Effectiveness for the Objective Function

Minimizing the transportation cost is then an objective function of this LP model. The LP model will present the way the transportation system should be operated in order to achieve the minimum transportation cost while all the other constraints involved are still fully met.

4.4 Represent a Linear Expression of a Measure of Effectiveness

A total transportation cost is a summation of transportation cost in each route, from each supply source to each depot. A transportation cost of each route can be calculated from *freight (baht/ton)* $\times$ *volume (tons)*. As a sample, a transportation cost from BRP to KKN by rail can be calculated from $c_1 \times x_1$ when c_1 is a rail freight from

BRP to KKN and x_1 is LPG volume transported from BRP to KKN by rail. For a truck freight which depends on a price of High-Speed Diesel Oil, a price of High-Speed Diesel Oil 11.00 baht/liter is assumed throughout all the calculations.

Hence, the objective function is shown as follows:

Minimize $c_1x_1+c_2x_2+c_3x_3+c_4x_4+c_5x_5+c_6x_6+c_7x_7+c_8x_8+c_9x_9$

where
c_1 = *rail freight from BRP to KKN, baht/ton*
c_2 = *rail freight from BRP to LMP, baht/ton*
c_3 = *rail freight from BRP to NSW, baht/ton*
c_4 = *truck freight from BRP to KKN, baht/ton*
c_5 = *truck freight from BRP to LMP, baht/ton*
c_6 = *truck freight from BRP to NSW, baht/ton*
c_7 = *truck freight from GSP LKB to KKN, baht/ton*
c_8 = *truck freight from GSP LKB to LMP, baht/ton*
c_9 = *truck freight from GSP LKB to NSW, baht/ton*

4.5 Identify and Represent Constraint

Constraints involved in this case are categorized into 3 main groups: a demand of each depot must be sufficiently served, a transportation capability is not exceeded, and a committed LPG at GSP LKB must be within the range of $\pm$ 5%. All the constraints can be described in term of linear expression as follows:

4.5.1 Demand of Each Depot

4.5.1.1 KKN Depot

$$x_1 + x_4 + x_7 = \textit{demand of KKN}$$

4.5.1.2 LMP Depot

$$x_2 + x_5 + x_8 = \textit{demand of LMP}$$

4.5.1.3 NSW Depot

$$x_3 + x_6 + x_9 = \textit{demand of NSW}$$

4.5.2 Rail Transportation Capability

There is a limitation in the total number of bogies and also the number of a locomotive engine provided by the State Railway of Thailand. There are 90 bogies in the present fleet. It can be divided in to approximately 4 rails consisting of 18-20 bogies per rail. The rest bogies must be scheduled for a preventive maintenance program. For the locomotive engine, now the State Railway of Thailand can procure only 4 locomotive engines per day for PTT. Therefore, this constraint can be presented in term of trip-day as follows:

turnaround time to KKN $\times$ *(number of rail sent to KKN) + turnaround time to LMP* $\times$ *(number of rail sent to LMP) + turnaround time to NSW* $\times$ *(number of rail sent to NSW)*

$\leq$

number of rails in each day $\times$ *number of days in that month*

The number of rail sent to each depot can be calculated as follows:

volume (tons) / rail capacity (tons/rail)

Hence, this constraint can be identified as follows:

$$turnaround\ time\ to\ KKN \times (x_1 / KKN\ rail\ cap.) + turnaround\ time\ to\ LMP \times (x_1 / LMP\ rail\ cap.) + turnaround\ time\ to\ NSW \times (x_3 / KKN\ rail\ cap.)$$
$$\le$$
$$number\ of\ rails\ in\ each\ day \times number\ of\ days\ in\ that\ month$$

4.5.3 Committed Volume

As described in Chapter 3, the LPG volume transported from GSP LKB must be varied within the range of the committed volume ±5%.

Therefore, this constraint can be presented as:

$$x_7 + x_8 + x_9 \le committed\ volume \times 1.05$$

and $$x_7 + x_8 + x_9 \ge committed\ volume \times 0.95$$

4.5.4 Nonnegativity Condition

The volume transported in any route must be positive value. Hence,

$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, and\ x_9 \ge 0$$

4.6 Collect Data for All Parameters

Now, all the parameters are going to identified as a constant.

4.6.1 Parameters of an Objective Function

A value of a transportation freight of each route: c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, and c_9 can be found in table 3.3, 3.4, and 3.5 in Chapter 3.

Therefore,

c_1 = 506.00 *baht/ton*

c_2 = 702.00 *baht/ton*

c_3 = 382.00 *baht/ton*

c_4 = 1,389.00 *baht/ton*

c_5 = 1,991.00 *baht/ton*

c_6 = 1,040.00 *baht/ton*

c_7 = 993.61 *baht/ton*

c_8 = 870.78 *baht/ton*

c_9 = 434.83 *baht/ton*

Hence, the objective function is

Minimize

$$506.00\, x_1 + 702.00\, x_2 + 382.00\, x_3 + 1{,}389.00\, x_4 + 1{,}991.00\, x_5 + 1{,}010.00\, x_6 + 993.61\, x_7 + 870.78\, x_8 + 434.83\, x_9$$

4.6.2 Parameters of Demand Constraint

These parameters were addressed in table 3.1, Chapter 3 as follows:

demand of KKN as of March, 2000 = 16,200 tons

demand of LMP as of March, 2000 = 12,600 tons

demand of NSW as of March, 2000 = 10,600 tons

Thus,

$$x_1 + x_4 + x_7 = 16,200$$

$$x_2 + x_5 + x_8 = 12,600$$

$$x_3 + x_6 + x_9 = 10,600$$

4.6.3 Parameters of Rail Constraint

As identified in Chapter 3, rail to KKN and LMP has a capacity of 458 tons while rail to NSW has a capacity of 510 tons. A number of days in March, 2000 is 31 days. Now, there are 4 rails used in the existing fleet.

Hence,

$$2\,(x_1/458) + 4(x_2/458) + 2\,(x_3/510) \leq 4 \times 31$$

or

$$x_1/458 + x_2/229 + x_3/510 \leq 62$$

4.6.4 Parameters of Committed Volume Constraint

From table 3.1, Chapter 3, the committed volume at GSP LKB as of March, 2000 is 9,100 tons.

Hence,

$$x_7 + x_8 + x_9 \le 9{,}100 \times 1.05$$

and $$x_7 + x_8 + x_9 \ge 9{,}100 \times 0.95$$

or

$$x_7 + x_8 + x_9 \le 9{,}555$$

and $$x_7 + x_8 + x_9 \ge 8{,}645$$

4.7 The LP Model of LPG Distribution System

From all the steps conducted, the final LP model is thus,

Minimize

$$506.00\,x_1+702.00\,x_2+382.00\,x_3+1{,}389.00\,x_4+1{,}991.00\,x_5+1{,}040.00\,x_6+993.61\,x_7+870.78\,x_8+434.83\,x_9$$

Subject to

$$x_1+x_4+x_7 = 16{,}200$$

$$x_2+x_5+x_8 = 12{,}600$$

$$x_3+x_6+x_9 = 10{,}600$$

$$2\,(x_1/458) + 4(x_2/458) + 2\,(x_3/510) \le 4 \times 31$$

$$x_7 + x_8 + x_9 \le 9{,}555$$

$$x_7 + x_8 + x_9 \ge 8{,}645$$

and $$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, \text{ and } x_9 \ge 0$$

4.8 Result of the LP Model as of March, 2000

To solve this LP model, a tool called Solver of Microsoft Excel is applied to generate the result. The result of the LP model is shown in table 4.1 on the next page.

Volume transported by truck from supply source x to depot y (at intersection): tons

Supply source	Konkhaen	Lampang	Nakornsawan	Total
LKB	0.00	9,555.00	0.00	9,555.00
BRP	0.00	1,706.61	0.00	1,706.61
Total	0.00	11,261.61	0.00	11,261.61

Volume transported by rail from supply source x to depot y (at intersection): tons

Supply source	Konkhaen	Lampang	Nakornsawan	Total
BRP	16,200.00	1,338.39	10,600.00	28,138.39

Total volume transported by rail and truck: tons

	Konkhaen	Lampang	Nakornsawan	Total
Total volume transported	16,200.00	12,600.00	10,600.00	39,400.00

Total volume receive from supply source: tons

LKB	9,555.00
BRP	29,845.00
Total	39,400.00

Total truck transportation cost from supply source x to depot y (at intersection): baht

Supply source	Konkhaen	Lampang	Nakornsawan	Total
LKB	0.00	8,320,302.90	0.00	8,320,302.90
BRP	0.00	3,397,856.33	0.00	3,397,856.33
Total	0.00	11,718,159.23	0.00	11,718,159.23

Total rail transportation cost from supply source x to depot y (at intersection):baht

Supply source	Konkhaen	Lampang	Nakornsawan	Total
BRP	8,197,200.00	939,551.25	4,049,200.00	13,185,951.25

Total rail and truck transportation cost: baht

	Konkhaen	Lampang	Nakornsawan	Total
Total transportation cost	8,197,200.00	12,657,710.49	4,049,200.00	24,904,110.49

Number of truck required: trucks

Supply source	Konkhaen	Lampang	Nakornsawan	Total
LKB	0.00	19.26	0.00	19.26
BRP	0.00	6.88	0.00	6.88
Total	0.00	26.15	0.00	26.15

Number of rail required: rails

Supply source	Konkhaen	Lampang	Nakornsawan	Total
BRP	35.37	2.92	20.78	59.08

Table 4.1: Result of the LP Model of LPG Distribution System as of March, 2000

4.9 The Initial LPG Distribution Plan as a Result of the LP Model According to the Present Management Policy

Initially, the LP model will be run according to the present management policy, not to invest in many more rails. This result will be analyzed whether or not it is suitable enough. If it is not, other management policies should be proposed and the further analysis will be conducted in order to figure out the optimal policy.

By putting a five-year-monthly-demand as addressed in table 3.6 into the LP model according to the present management policy, 4 rails and no rail is added, an initial quantity of rail and truck required for each month is summarized in table 4.2. In addition, transportation trips, volume allocation, transportation cost, and transportation cost per unit volume are also illustrated in appendix A, appendix B, appendix C, and appendix D respectively.

Unit: rails,trucks

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	% Growth
2001	**Truck**	30	30	24	27	25	27	33	36	35	31	38	39	**31**	-
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4**	-
2002	**Truck**	38	37	32	34	32	34	40	44	43	38	47	47	**39**	**24.13**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4**	-
2003	**Truck**	45	45	39	41	39	42	48	52	51	46	55	55	**46**	**19.45**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4**	-
2004	**Truck**	54	48	46	49	46	49	56	60	58	53	62	63	**54**	**15.65**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4**	-
2005	**Truck**	61	61	54	57	53	57	64	68	66	60	70	71	**62**	**15.28**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4**	-

Table 4.2: Number of Rails and Trucks Required (No rail is added)

When the number of rail is frozen according to the present management policy, the demand beyond the capacity of rail transportation must be transported by truck only. As generally known that truck freight is more expensive than that of rail. Hence, this policy makes the transportation cost per unit volume continuously increases. Obviously seen in table 4.3, the transportation cost per unit volume in each year significantly grown up. Hence, there should be a further study whether or not the present management policy is the optimal solution for the next five years.

Year	**Volume** (tons)	**Transportation cost** (baht)	**Transportation cost/volume** (baht/ton)	**±%**
2001	485,300	324,457,534	667.161	-
2002	516,300	370,329,735	715.964	7.32
2003	547,300	416,202,408	759.673	6.10
2004	577,500	461,250,189	797.436	4.97
2005	608,800	509,388,989	835.709	4.80

Table 4.3: Growth of Transportation Cost per Unit Volume

Other policies will be proposed to compare it results with that of the present one. The proposed alternative will be initially done by removing the rail capability constraint in order to find the maximum number of rail that the system actually requires. This maximum number of rail will be used as a boundary to limit the scope of the experiment in a simulation study which can create more practical solution than the LP does.

4.10 Number of Rails Actually Required by the System as a Result of the LP Model

In order to decrease the average transportation cost per unit volume, rail should be added into the system. However, buying rail is quite high investment. Therefore, there should be a study to find the optimum solution whether or not rail should be bought. If it is, next questions are how many and when rails should be added into system.

As discussed in Chapter 3, the process of buying new rail takes quite long time, 3 years. Thus, if the management decides to buy new rail at the end of the year 2000, new rail will be added into the system at the beginning of the year 2004. Consequently, there will be no change in the LP result of the year 2001 through the year 2003.

Consequently, the LP model will be run without the constraint that limits the rail capability in order to figure out the exact number of rail that the system really requires.

In order to identify the exact number of rail that the system requires, the constraints number *(4)* will be removed from the model. The adjusted model can be illustrated as follows:

Minimize

$$506.00\,x_1 + 702.00\,x_2 + 382.00\,x_3 + 1{,}389.00\,x_4 + 1{,}991.00\,x_5 + 1{,}040.00\,x_6 + 993.61\,x_7 + 870.78\,x_8 + 434.83\,x_9$$

Subject to

$$x_1 + x_4 + x_7 = 16{,}200 \qquad (1)$$

$$x_2 + x_5 + x_8 = 12{,}600 \qquad (2)$$

$$x_3 + x_6 + x_9 = 10{,}600 \qquad (3)$$

$$x_7 + x_8 + x_9 \leq 9{,}555 \qquad (4)$$

$$x_7 + x_8 + x_9 \geq 8{,}645 \qquad (5)$$

and $$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, \text{ and } x_9 \geq 0 \qquad (6)$$

By applying this adjusted model with the LPG distribution system as of year 2004 and 2005, the volume transported by rail in each month can be addressed in table 4.4. The actual number of rails that the system requires can be calculated by using the following relationship.

$$2(x_1/458) + 4(x_2/458) + 2(x_3/510) \quad \leq \text{number of rails} \times \text{number of days}$$

Value on the left-hand side presents the total trips-days that the system requires in each year. Thus, the number of rail can be calculated from the total trips-days divided by the number of days in that year. In year 2004 and 2005, there are 366 and 365 days respectively. This calculation is summarized in table 4.5.

Unit: tons

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	KKN	19,200	17,400	18,300	18,600	19,000	18,700	20,000	20,300	19,900	19,500	19,900	20,900	231,700	19,308
2,004	LMP	16,800	15,000	15,800	15,600	15,600	15,500	17,000	17,600	16,300	16,500	17,300	17,900	196,900	16,408
	NSW	4,112	3,373	3,312	3,093	3,012	3,293	3,812	4,412	4,693	4,012	4,593	4,612	46,329	3,861
	Total	***40,112***	***35,773***	***37,412***	***37,293***	***37,612***	***37,493***	***40,812***	***42,312***	***40,893***	***40,012***	***41,793***	***43,412***	***474,929***	***39,577***
	KKN	20,200	18,300	19,200	19,500	19,900	19,600	20,900	21,300	20,900	20,400	20,800	21,800	242,800	20,233
2,005	LMP	17,900	16,000	16,900	16,600	16,600	16,500	18,200	18,700	17,400	17,600	18,400	19,100	209,900	17,492
	NSW	4,712	4,253	3,912	3,693	3,612	3,893	4,412	5,012	5,293	4,612	5,193	5,212	53,809	4,484
	Total	***42,812***	***38,553***	***40,012***	***39,793***	***40,112***	***39,993***	***43,512***	***45,012***	***43,593***	***42,612***	***44,393***	***46,112***	***506,509***	***42,209***

Table 4.4: LPG Volume Transported by Rail as a Result of the LP Model as of 2004-2005 (Unlimited Rail)

2004	Volume by rail (tons)	Rail capacity (tons/rail)	Trips	Turn-around time (days)	Trips-days	Number of rail required (rails)
KKN	231,700	458	505.90	2	1,011.79	2.76
LMP	196,900	458	429.91	4	1,719.65	4.70
NSW	46,329	510	90.84	2	181.68	0.50
Total	**474,929**	**-**	**1,026.65**	**-**	**2,913.12**	**7.96**

2005	Volume by rail (tons)	Rail capacity (tons/rail)	Trips	Turn-around time (days)	Trips-days	Number of rail required (rails)
KKN	242,800	458	530.13	2	1,060.26	2.90
LMP	209,900	458	458.30	4	1,833.19	5.02
NSW	53,809	510	105.51	2	211.01	0.58
Total	**506,509**	**-**	**1,093.94**	**-**	**3,104.46**	**8.51**

Table 4.5: Number of Rails that the System Actually Required

From table 4.5, in the year 2004 and 2005, 7.96 and 8.51 rails are required in order to generate the lowest transportation cost respectively. They are the highest numbers of rails that are possible in an operation and will be used as a boundary to limit the scope of simulation study. However, they are only the possible numbers that have not been analyzed together with the investment in buying new rail. This investment analysis will be done in the simulation part in the next chapter.

However, 7.96 and 8.51 rails is impossible in real operation because they are not an integer number though they make the lowest transportation cost. Nevertheless, concerning about only the lowest transportation cost is not enough because the investment in buying new rail must be added into consideration. Too many rails result in idle time resulting in unnecessary higher expense. On the contrary, too low number of rail results in high total transportation cost because truck transportation which has a higher freight will play more important role. Moreover, in real operation, there are many factors involved that are unable to be explained in term of deterministic expression such as variations in transportation turnaround time, fluctuation in demand, failure of transportation vehicle, etc. These uncertainties may cause setting LPG distribution plan deviates from the optimal point. Hence, in order to cover these factors, a simulation should be applied with this problem to create more practical solution.

4.11 Primary Number of Rails and Trucks Required

Before applying the simulation technique, the LP model will be exploited in order to figure out a rough quantity of rails and trucks required for 5-year-period when rails is added into the system. However, as discussed in the previous part, this solution is just a theoretical guideline. It may not be appropriate enough to be implemented in the real operation since it does not absorb some uncertainties that occur in the actual world. The purpose of providing this approximate solution is to compare this solution with the more practical solution given by the simulation model in order to see how all the uncertainties have an affect on the primary solution.

In running the LP model to find out this approximate solution, the customer's demand exactly according to the plan will be put into the model. After that, number of rails will be added into the system one by one to identify the theoretical solution of each case. The total number of rail and trucks required is addressed in table 4.6.

Unit: rails,trucks

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
2001	**Truck**	30	30	24	27	25	27	33	36	35	31	38	39	**31.26**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4.00**
2002	**Truck**	38	37	32	34	32	34	40	44	43	38	47	47	**38.80**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4.00**
2003	**Truck**	45	45	39	41	39	42	48	52	51	46	55	55	**46.37**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4.00**
	Truck for 4 rails	54	48	46	49	46	49	56	60	58	53	62	63	**53.60**
	Truck for 5 rails	39	33	31	34	31	35	41	45	43	38	47	47	**38.71**
2004	**Truck for 6 rails**	24	19	19	20	19	20	26	30	29	24	33	33	**24.78**
	Truck for 7 rails	19	19	19	19	19	19	19	19	19	19	19	19	**19.36**
	Truck for 8 rails	18	18	18	18	18	18	19	19	19	18	19	19	**18.25**
	Truck for 4 rails	61	61	54	57	53	57	64	68	66	60	70	71	**61.80**
	Truck for 5 rails	46	46	39	42	38	42	48	52	51	45	55	55	**46.54**
2005	**Truck for 6 rails**	32	31	24	27	24	27	34	38	36	31	40	41	**32.23**
	Truck for 7 rails	19	19	19	19	19	19	20	24	22	19	26	27	**21.12**
	Truck for 8 rails	19	19	18	19	18	19	19	19	19	19	19	19	**19.05**
	Truck for 9 rails	18	18	18	18	18	18	18	18	18	18	19	19	**17.75**

Table 4.6: Number of Rail sand Trucks Required as a Result of the LP Model (Rail is Added)

4.12 Comparison between the Plan from the LP Model and the Plan from the Present Logical Concept

Next, a comparison between the plan as a result of the LP model and the plan in actual operation using a present decision logic as of March, 2000, described in Chapter 3, is illustrated in table 4.7, table 4.8, and table 4.9, on the next page.

From tables 4.9, transportation cost per unit of the two cases is slightly different. The plan created from a logical concept is higher than that of the LP model which is the optimal cost, 21.64 baht/ton or 3.42%. This variation is caused by some actual operation constraints that cannot be put into the LP model such as the volume transported must be a multiple of a transportation capacity. For example, LPG volume sent to KKN by rail must be a multiple of 458 such as 916, 1,374, and so on. The volume of 880.39 tons as a result from the LP model is impossible according to this restriction. Moreover, an integer effect also plays an important role in real operation. For example, 35.37 rails should be sent to KKN, but in real operation 35.37 rails are impossible. An integer value of 35 or 36 must be sent instead. In order to minimize the total transportation cost, 36 rails are sent to KKN as shown in table 3.2. Similarly, 21 rail are sent to NSW instead of 20.78. Consequently, in order to maintain the constraint of rail capacity, only 2 rails can be sent to LPM although the LP model suggests that 2.92 rails should be sent to LMP. This is because if 3 rails are sent to LMP, the total number of rail sent in this month will exceed the maximum capacity of rail transportation.

According to these reasons why the real case operation differs from the LP result, the LPG distribution plan nowadays can be primary proved that it is practical and can be continued to be applied in setting the LPG distribution plan.

Unit: tons

	Rail from BRP				Truck from BRP				Truck from LKB				Total			
	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %
KKN	16,200.00	16,488.00	288.00	1.78	0.00	0.00	0.00	-	0.00	0.00	0.00	-	16,200.00	16,488.00	288.00	1.78
LMP	1,338.39	916.00	-422.39	-31.56	1,706.61	2,480.00	773.39	45.32	9,555.00	9,145.00	-410.00	-4.29	12,600.00	12,541.00	-59.00	-0.47
NSW	10,600.00	10,710.00	110.00	1.04	0.00	0.00	0.00	-	0.00	0.00	0.00	-	10,600.00	10,710.00	110.00	1.04
Total	28,138.39	28,114.00	-24.39	-0.09	1,706.61	2,480.00	773.39	45.32	9,555.00	9,145.00	-410.00	-4.29	39,400.00	39,739.00	339.00	0.86

Table 4.7: Comparison of Allocation Volume

Unit: baht

	Rail from BRP				Truck from BRP				Truck from LKB				Total			
	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %
KKN	8,197,200.00	8,342,928.00	145,728.00	1.78	0.00	0.00	0.00	-	0.00	0.00	0.00	-	8,197,200.00	8,342,928.00	145,728.00	1.78
LMP	939,551.25	643,032.00	-296,519.25	-31.56	3,397,856.33	4,937,680.00	1,539,823.67	45.32	8,320,302.90	7,963,283.10	-357,019.80	-4.29	12,657,710.49	13,543,995.10	886,284.61	7.00
NSW	4,049,200.00	4,091,220.00	42,020.00	1.04	0.00	0.00	0.00	-	0.00	0.00	0.00	-	4,049,200.00	4,091,220.00	42,020.00	1.04
Total	13,185,951.25	13,077,180.00	-108,771.25	-0.82	3,397,856.33	4,937,680.00	1,539,823.67	45.32	8,320,302.90	7,963,283.10	-357,019.80	-4.29	24,904,110.49	25,978,143.10	1,074,032.61	4.31

Table 4.8: Comparison of Transportation Cost

	Total Volume (tons)				Total Transportation Cost (baht)				Transportation Cost per Unit Volume (baht/ton)			
	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %	LP Model	Logical Concept	Difference	+/- %
KKN	16,200.00	16,488.00	288.00	1.78	8,197,200.00	8,342,928.00	145,728.00	-	506.00	506.00	0.00	-
LMP	12,600.00	12,541.00	-59.00	-0.47	12,657,710.49	13,543,995.10	886,284.61	7.00	1,004.58	1,079.98	75.40	7.51
NSW	10,600.00	10,710.00	110.00	1.04	4,049,200.00	4,091,220.00	42,020.00	-	382.00	382.00	0.00	-
Total	39,400.00	39,739.00	339.00	0.86	24,904,110.49	25,978,143.10	1,074,032.61	4.31	632.08	653.72	21.64	3.42

Table 4.9: Comparison of Transportation Cost per Unit Volume

4.13 Some Interesting Points Noticed from the LP Result

From the results shown in table 4.1, there are some interesting points that should be focused on and should be used as a guideline in setting the LPG distribution plan with the existing number of rails, 4 rails, as follows:

- Rail transportation. Rail should be sent to sufficiently serve the demand at KKN first after that it should be sent to NSW and LMP respectively.
- Truck transportation from GSP LKB. Truck from GSP LKB should go to LMP depot only. Moreover, this transported volume always reaches an upper limit of the committed volume. This means PTT should try to receive as much as possible from GSP LKB.
- Truck transportation form BRP. Truck from BRP is the complement to fulfill the rest volume that cannot be covered by the rail transportation.

These things found from the result of LP model is relatively the same as the logical concept used in setting the LPG distribution plan nowadays.

In the next chapter, simulation will be applied to propose other rail investment policies by using the initial maximum number of rail required as a boundary of the experiment.

CHAPTER 5

APPLYING SIMULATION THEORY IN LPG DISTRIBUTION SYSTEM

In the present world where the computer technologies are rapidly developed, LP seems to be less interesting. The solution run from the LP model may be not attractive enough toward the users. Moreover, for the case of LPG distribution plan that is going to be studied in the thesis, some of its characteristics may be not appropriate to be expressed in term of linear function such as a fluctuation in demand, a variation in transportation lead time, a transportation failure, a transportation size, etc. These uncertainties cannot be completely covered by LP. Hence, a simulation will be exploited in the second step of solving the LPG problem.

In order to achieve a more practical solution, a simulation study is then conducted in this chapter. A simulation model will be constructed to make it works as initially guided by the LP model. Initial logic solution achieved from the LP model will be used as a basis to primarily validate the LPG simulation model. Additionally, in order to improve an initial solution gained from the LP model, the uncertainties and also other constraints that unable to be included in the LP model will be added to the simulation model to make it more practical for actual working operation.

In the year 2001-2003, the model will be run with the existing number of rails, 4 rails, because the procurement process of new rail takes at least 3 years as previously discussed. The new rail can join the system no prior to the beginning of the year 2004. For the year 2004 and 2005, the model will be run with an increasing number of rails one by one until the total number of rail in the system is equal to the maximum possible number of rails guided by the LP model. After that, the total transportation cost of each case together with the investment in new rails will be analyzed together in order to find out the optimal solution for the system in the next 5 years. Lastly, the optimal solution selected will be proposed as the final output of this thesis.

5.1 Define the Problem and Set the Objective

It is necessary to understand the problem clearly in order to devise the useful approach for solving it, stated by Robinson (1994). This idea is supported by John Dewey (quoted in Lubart, 1994), A problem well put is half solved. Hence, the problem that is going to be studied in this chapter should be clearly defined first.

5.1.1 Define the Problem

Details of the existing problem have already been discussed in Chapter 3, however, they may be summarized here again as follows:

1. In the nowadays working, there is no decision-making tool used to help setting the LPG distribution plan that generates a suitable transportation cost. Everything is based on an experience of the scheduler.
2. While the customers' demand is increasing, there is no preparation for the transportation system in order to sufficiently serve the customers' demand in the future. Pattern of the LPG distribution system in the future has not been figured out yet.

In order to emphasize on this problem, the increased customers' demand is illustrated in figure 5.1.

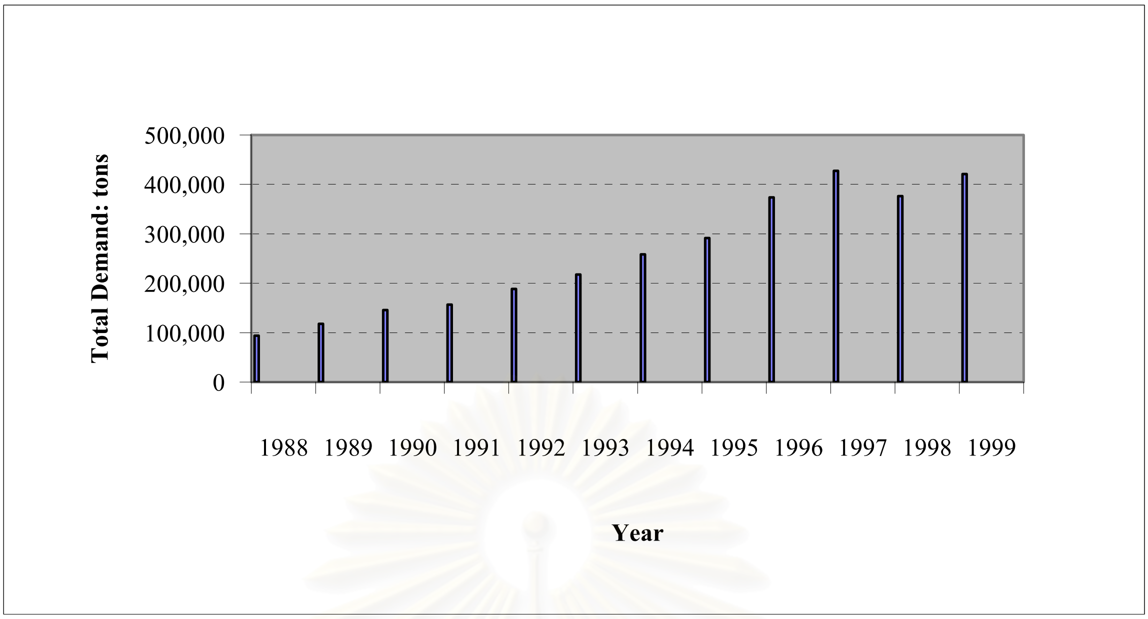

Figure 5.1: The Total Customers' Demand (KKN, LMP, and NSW) 1998-1999

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.1.2 Set the Objective

The objective of this simulation study is to investigate the characteristics of the LPG transportation against the various monthly demands of KKN, LMP, and NSW depot. These characteristics of the LPG transportation will be further analyzed in order to set a five-year LPG distribution plan.

5.2 Identify Experiment Factor

Experiment factors are inputs of the simulation model. According to Pidd (1998), inputs may be categorized into two groups: inputs that define the configuration of the system, and inputs that are random samples from the various probability distributions.

For the case of LPG distribution system, these inputs may be defined as follows:

5.2.1 Inputs that Define the Configuration of the System

1. Number of rail and truck in the system
2. Maximum working capacity of the LPG sphere at each area
3. Transportation capacity of rail and truck
4. Number of loading bay at supply sources
5. Number of unloading bay at destination depots
6. Working hour of each area

5.2.2 Inputs that are the Random Samples from the Various Probability Distributions

1. Demand of each destination depot
2. Rail and truck transportation turnaround time of each route
3. Rail and truck failure rate
4. Rail and truck loading time
5. Rail and truck unloading time

By giving these inputs into the simulation model, the following outputs should be achieved as a result of the simulation.

1. Total quantity of rail required
2. Total quantity of truck required
3. LPG volume transported by rail from BRP to each destination depot
4. LPG volume transported by truck from each supply source to each destination depot

5. Total trip of rail and truck transporting from each supply source to each destination depot
6. Transportation cost of each route
7. Percentage of rail utilization
8. Percentage of truck utilization
9. Percentage of resource utilization at each area

Pidd (1998) states that a simulation experiment involves subjecting the model to inputs and interpreting their effects on the outputs. The relationship between the inputs and out puts is can be shown in figure 5.2.

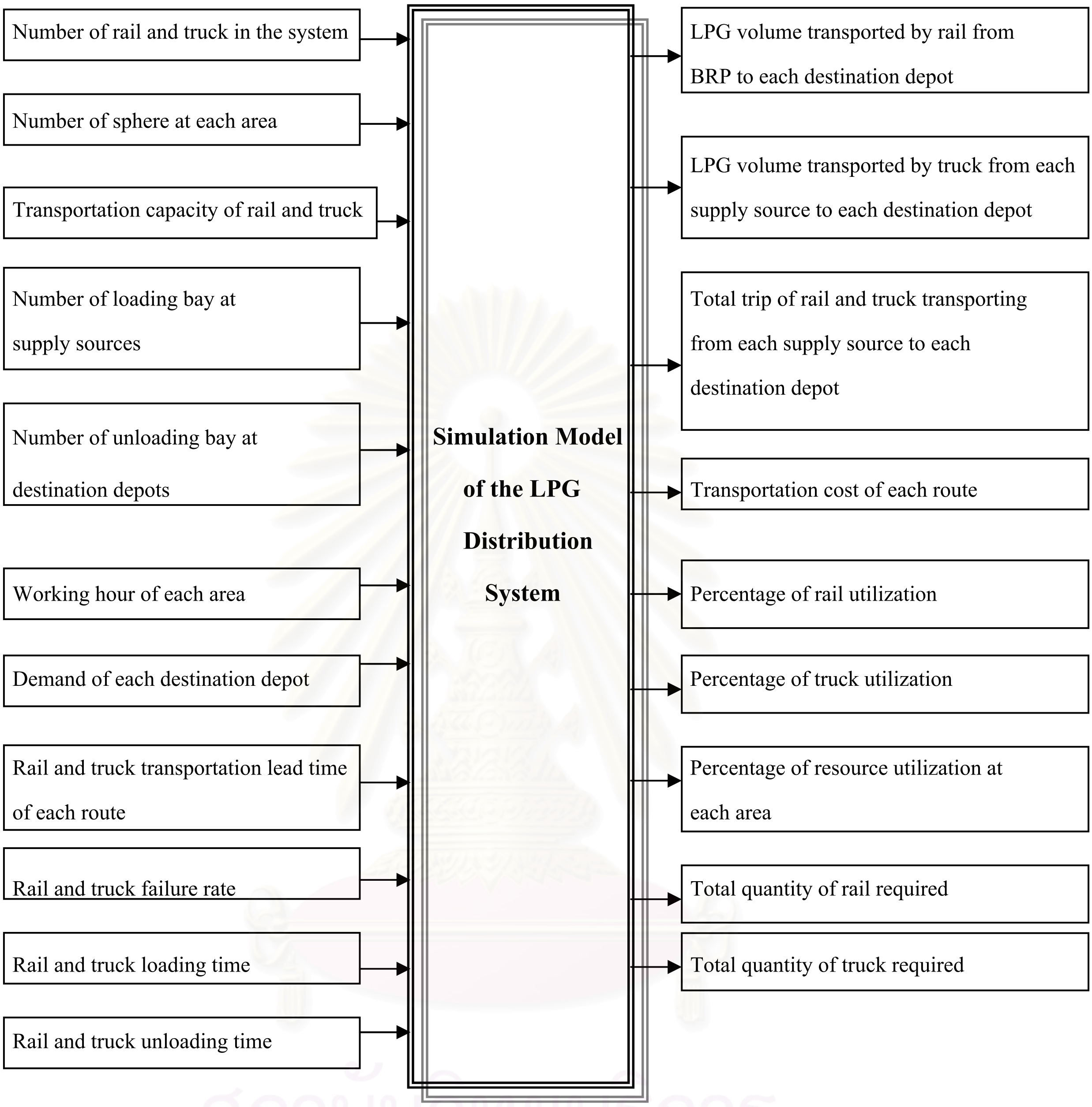

Figure 5.2: Formulation Simulation Experimentation

Source: Adapted from Michael Pidd, 1998, Computer Simulation in Management Science, Fourth Edition, John Wiley & Sons Ltd., Chapter 12, page 197

5.3 Determine the Scope and Level of the Model

In this step, it is about making a decision upon the scope to specify what should be included in the model and level to clarify how much detail should be modeled. It is said that the basic rule of what to include in the model is that to minimize the amount of details as long as the project's objectives still can be achieved.

5.3.1 Determine the Scope of the Model

1. The model will mimic the LPG distribution system to the depots only in the North and the Northeast: KKN, LMP, and NSW depot.
2. Transporters used in the model are only rail and truck.
3. The supply sources involved are BRP and GSP LKB.
4. The model will illustrate only the transportation of LPG from the supply sources to the destination depots. Receiving LPG from the gas separation plant and selling LPG to the customers will not be shown here.

5.3.2 Determine the Level of the Model

The details that will be modeled here involve in a set of activities and also entities. In order to clearly clarity these issues, Flow Process Chart, and Activity Cycle Diagram, are applies to complete this purpose.

5.3.2.1 Flow Process Chart

In order to give a clear perception of how the system works, a flow process chart will be applied with the LPG distribution system.

As previously address in Chapter 3, part 3.2.4, daily events that occurs in everyday working operation can be explained in form of more logical way using a flow process chart as illustrated in table 5.1.

Activity	**Operation**	**Transportation**	**Inspection**	**Delay**	**Storage**
- Operators at supply sources starts preparing spheres. LPG is transferred through a pipeline system.	○	●	□	D	▽
- LPG is kept in spheres.	○	⇨	□	D	●
- Operators at supply sources check for the quality of LPG.	○	⇨	●	D	▽
- Transporters leave the base site and go to the loading stations at supply sources.	○	●	□	D	▽
- Transporters wait for a loading queue.	○	⇨	□	●	▽
- Operators at supply sources starts loading.	●	⇨	□	D	▽
- Transporters travel to the destination depots.	○	●	□	D	▽
- Transporters waits for unloading.	○	⇨	□	●	▽
- Operators at depots unload LPG from transporters.	●	⇨	□	D	▽
- LPG is kept in spheres.	○	⇨	□	D	●
- Transporters go back to the base.	○	●	□	D	▽
- Operators at destination depots sell LPG to the customers.	●	⇨	□	D	▽

Table 5.1: A Flow Process Chart of the Daily Operation of the LPG Distribution System

A flow process chart shown in table 5.1 just illustrates a roughly description of the system. It does not give a crystal clear of details. Next, an activity cycle diagram will be applied with the system to provide a clearly understanding.

5.3.2.2 Activity Cycle Diagram

In order to visualize the operations of the entities in the system, an activity cycle diagram is used to model the interactions of these entities. A simulation model going to be constructed in this chapter is based upon the interaction described in the LPG distribution activity cycle diagram illustrated in figure 5.7. Firstly, classes of entities involved will be identified. Next, activities in which each engage will be addressed. Lastly, all the activities that every entity engage in will be linked together to create an activity cycle diagram of the LPG distribution system as shown in figure 5.7.

Entities of the system may be categorized into four classes as follows:

(1) Operators at supply sources
(2) Operators at destination depot
(3) LPG itself
(4) Transporters

Next, active states and dead states of each entity are going to be discussed.

(1) Operators at supply sources

Active State

1) Loading refers to the event that the operators at supply sources are loading LPG to transporters.

2) Away1 refers to the event that operators at supply sources are not on duty.

Dead State

1) Idle1 refers to the event that operators at supply sources are waiting for the next transporter to come to the loading site.

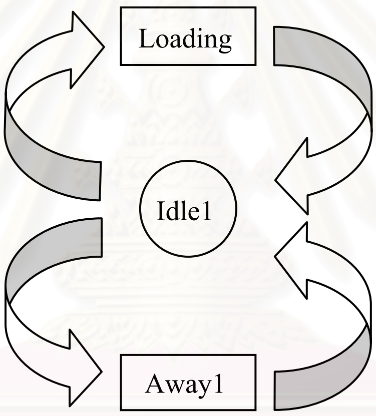

Figure 5.3: Activity Cycle Diagram of Operators at Supply Sources

(2) Operators at destination depots

Active State

1) Unloading refers to the event that operators at destination depots are receiving LPG from transporters.

2) Away2 refers to the event that operators at destination depots are not on duty.

Dead State

1) Idle2 refers to the event that operators at destination depots are waiting for the next transporter to arrive the unloading site.

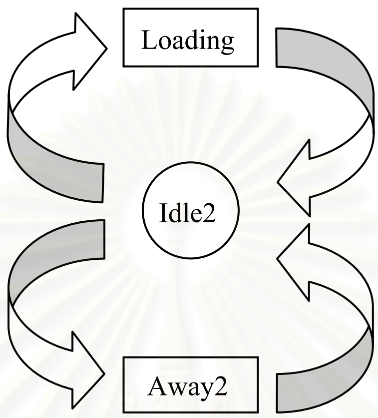

Figure 5.4: Activity Cycle Diagram of Operators at Destination Depots

(3) LPG

Active State

1) GSP refers to the event that LPG is sent from GSP Rayong or GSP LKB to the spheres at supply sources through the pipeline system.

2) Loading refers to the event that LPG in sphere at supply sources is loaded to transporters by operators at supply sources.

3) Go refers to the event that LPG together with the transporters are going to the assigned destination depots.

4) Unloading refers to the event that LPG in the tank of transporters is being unloaded from the transporters by operators at destination depots.

5) Customer refers to the event that LPG kept in sphere at destination depots is sold to customers.

Dead State

1) Store1 refers to the event that LPG is kept in spheres at supply sources.

2) Ready refers to the event that the process of loading LPG to the tank of transporters is just finished by operators at supply sources.

3) OK refers to the event that LPG together with transporters just arrived the destination depots waiting for unloading.

4) Store 2 refers to the event LPG is kept in spheres at destination.

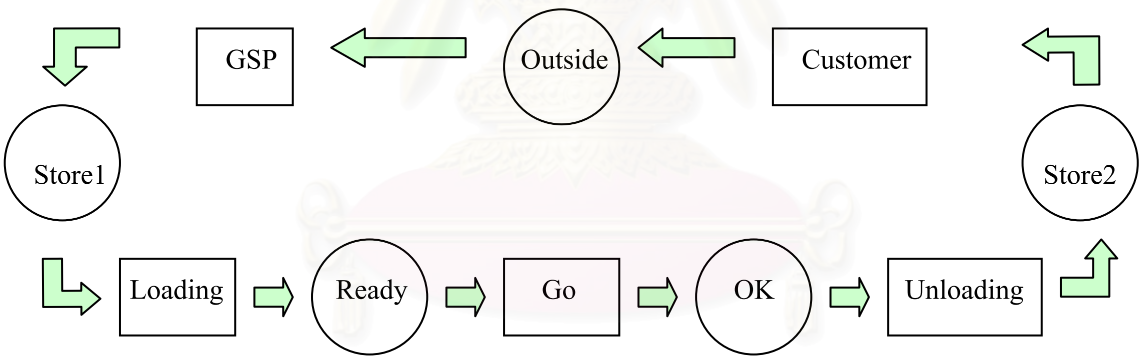

Figure 5.5: Activity Cycle Diagram of LPG

(4) Transporters

Active State

1) Loading refers to the event that transporters are at supply sources and being fulfilled with LPG by operators at supply sources.

2) Go refers to the event that transporters that are filled with LPG are travelling to the assigned destination depots.

3) Unloading refers to the event that transporters are being unloaded LPG by operators at the destination depots.

4) Back refers to the event that empty transporters are going back from destination depots heading to the base site.

Dead State

1) Ready refers to the event that the process of loading LPG to the tank of transporters is just finished by operators at supply sources. Then the transporters are ready to start travelling to the assigned destination depots.

3) OK refers to the event that the loaded transporters just arrived the destination depots waiting for unloading.

3) Empty refers to the event that transporters just finish unloading process and going to go back to the base site.

4) Idle3 refers to the event that empty transporters are at the base site waiting for a loading command.

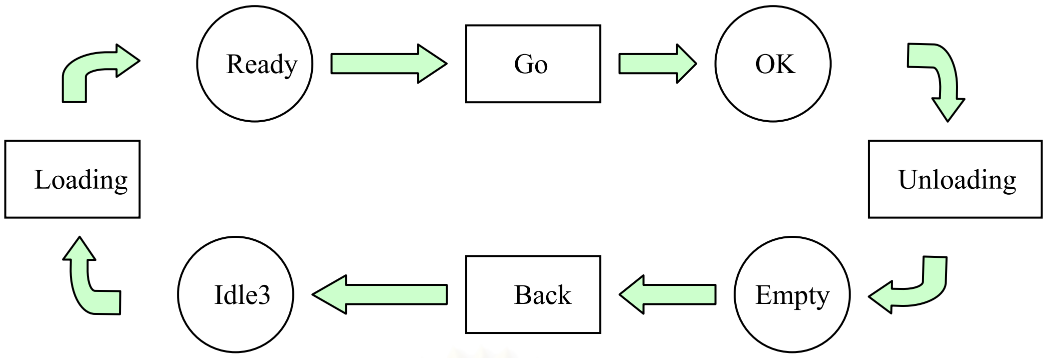

Figure 5.6: Activity Cycle Diagram of Transporters

All details describes above are entities and activities in which each of them engage. An activity cycle diagram of the LPG distribution system can be obtained by linking together all the activities of these entities as shown in figure 5.7.

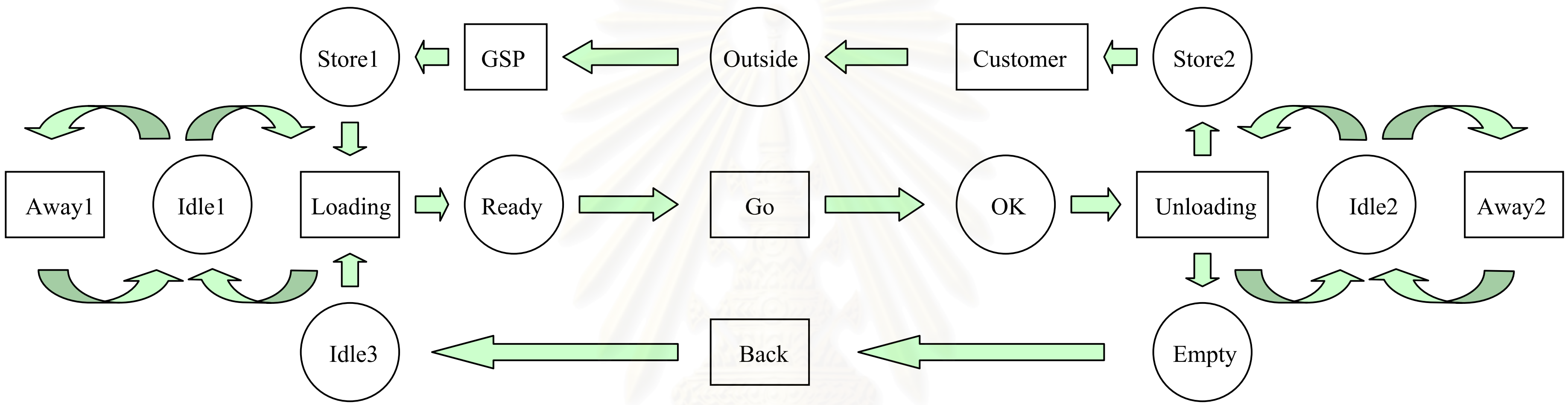

Figure 5.7: Activity Cycle Diagram of the LPG Distribution System

The flow process chart and the activity cycle diagram show how the operations in the working field occur and also illustrate the interactions among the entities within the system. In setting plan, the scheduler will make a decision based upon the logic concept guided by the LP model as discussed in Chapter 4.

For rail, it will be sent to cover the demand of KKN, NSW, and LMP respectively.

For case of truck from GSP LKB, the volume that will be lift from GSP LKB in everyday is equal to the committed volume divided by the number of days in the month.

For a case of truck from BRP, it is a fulfillment to cover the rest volume that is beyond the capacity of rail and GSP LKB. Daily truck transportation that should be sent from BRP can be calculated from this rest of volume divided by the number of days in the month. Moreover, whenever the stock at depot is too low because of the fluctuation in demand, the other unexpected events, etc., the number of trucks sent in each day will be automatically increased in order to bring the stock back to the normal status as soon as possible.

5.4 Collect and Analyze the Data

In this step, all data required for constructing the model will be gathered, formatted, and analyzed in order to make them ready for use. Data going to be collected may be divided into two categories: data that define the configuration of the system and data that are the random samples from the various probability distributions.

5.4.1 Data that Defines the Configuration of the System

5.4.1.1 Number of Rail and Truck in the System

1. Rail

As previously stated in chapter 3, PTT has its own 90 bogies. 18-20 bogies will be combined to make 1 rail.

2. Truck

There are 45 trucks used in transportation activity now. These trucks are divided into 2 fleets. The first one, 20-25 trucks, transports LPG from BRP to destination depot. For the second one, the rest 20-25 trucks travel from GSP LKB to any of the regional depots. As discussed in Chapter 3, the total number of truck can be unlimited increased by finding new truck contractors or expanding the capacity of the existing contractor.

5.4.1.2 Maximum Working Capacity of the LPG Sphere at Each Area

Working Area	**Maximum Storage Capacity** (tons)
BRP	2,550
GSP LKB	1,500
KKN	1,700
LMP	1,700
NSW	1,700

Table 5.2: Maximum Working Capacity of the LPG Sphere at Each Area

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.1.3 Transportation Capacity of Rail and Truck

Transportation Mode		**Capacity** (tons)
Rail	1 bogie	25.5
	Rail to KKN (18 bogies)	458.0
	Rail to LMP (18 bogies)	458.0
	Rail to NSW (20 bogies)	510.0
Truck		16.0

Table 5.3: Transportation Capacity of Rail and Truck

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.1.4 Number of Loading Bay at Supply Sources

Supply Source	**Number of Loading Bay** (bays)
Truck loading bay at BRP	2
Truck loading bay at GSP LKB	4
Rail loading bay at BRP	1

Table 5.4: Number of Loading Bay at Supply Sources

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.1.5 Number of Unloading Bay at Destination Depot

Destination Depot	**Number of Unloading Bay** (bays)
Truck unloading bay at KKN	2
Truck unloading bay at LMP	3
Truck unloading bay at NSW	2
Rail unloading bay at KKN	1
Rail unloading bay at LMP	1
Rail unloading bay at NSW	1

Remark: Only for unloading purpose, not include loading LPG to the customer

Table 5.5: Number of Unloading Bay at Destination Depot

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.6 Working Hour of Each Area

Working Area	Loading/Selling	Receiving
BRP	08:00 a.m. – 12:00 p.m.	24 hours
GSP LKB	24 hours	24 hours
KKN	08:00 a.m. – 06:00 p.m.	08:00 a.m. – 12:00 p.m.
LMP	08:00 a.m. – 06:00 p.m.	08:00 a.m. – 12:00 p.m.
NSW	08:00 a.m. – 06:00 p.m.	08:00 a.m. – 12:00 p.m.

Table 5.6: Working Hour of Each Area

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

However, the working schedule of these depots can be adjusted to serve any change in situation. For example, if the demand in the future becomes larger, the depots may have to expand the period of their working hours.

5.4.2 Data that are the Random Samples from the Various Probability Distribution

According to Kelton et. al. (1998), there are three measures of a distribution's fit to data: mean square error, chi-square, and Kolomogorov-Smirnov (K-S) goodness-of-fit hypothesis test. The mean square error is the simplest approach. It is the average of the mean square error terms of each histogram cell, which are the squares of the differences between the relative frequencies of the observations in a cell and the relative frequency for the fitted probability distribution function over that cell's data range. The larger the square error value, the further away the distribution is from the actual data. For chi-square and K-S, the corresponding p-value, which always fall between 0 and 1 is computed. The larger p-values indicate better fit of distribution.

These theoretical issues will be applied with the collected data. Data analysis will be conducted with a helping hand of ARENA 3.01, Input Analyzer Module.

5.4.2.1 Demand of Each Destination Depot

Appendix E shows the demand of each destination depot in 1999. These data are analyzed to figured out a suitable probabilistic expression. The probabilistic distributions of the demand of each depot in each month are shown in forms of best-fitted curve and expression.

From appendix E, average difference between the actual demand and the planned demand and also the percentage of standard deviation of the actual daily demand can be summarized in table 5.7.

Unit: %

	KKN	**LMP**	**NSW**
% difference from monthly planned demand	+7.61	+3.60	-2.16
% of standard deviation of actual daily demand	15.33	11.63	12.33

Table 5.7: Deviation of Actual Demand Compared with Plan

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.2.2 Transportation Turnaround Time

Turnaround time of each transportation route and also best fitted curve and expression are collected addressed in Appendix F. For rail transportation, the time spent from the supply source to the destination and that of from the destination back to the supply source are significantly different. So, the transportation turnaround time of rail is categorized into 2 groups, back and forth. For truck, there is no significant difference between going out and coming back.

However, for truck transportation in some routes have never occurred or hardly occurred. Therefore, an actual turnaround time of these routes cannot be collected. Thus, the transportation turnaround time for these routes are just an approximated time given by the truck contractor of PTT, SC Management Co., Ltd. Transportation turnaround time in each route used in constructing the model are summarized as shown in table 5.8.

Unit: minutes

	Route	Expression
Rail	From BRP to KKN	NORM (876, 76.4)
	From KKN to BRP	NORM (744, 94.9)
	From BRP to LMP	NORM (1.65e+003, 112)
	From LMP to BRP	NORM (1.24e+003, 99.9)
	From BRP to NSW	NORM (663, 85.9)
	From NSW to BRP	NORM (746, 65.4)
Truck	BRP-KKN	600 (constant: not enough data)
	BRP-LMP	NORM (968, 18.5)
	BRP-NSW	420 (constant: not enough data)
	GSP LKB-KKN	540 (constant: not enough data)
	GSP LKB-LMP	NORM (306, 18)
	GSP LKB- NSW	150 (constant: not enough data)

Table 5.8: Transportation Turnaround Time

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.2.3 Failure Rate

In Appendix G, there are raw data of rail and truck failure rate. The data are collected in term of frequency and duration of each failure. Probabilistic functions of these data are illustrated in appendix G as well. Expressions of failure frequency and failure duration of both rail and truck are illustrated in table 5.9.

Unit: minutes

Transporter	Frequency of Failure	Duration of Failure
Rail	1.44e+003 + EXPO(5.99e+004)	78 + EXPO(598)
Truck	1.44e+003 + EXPO(1.66e+003)	720 + EXPO(4.49e+003)

Table 5.9: Frequency and Duration of Failure

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.2.4 Loading Time

Rail and truck loading time are obtained from an operating record of BRP and GSP LKB. Raw data collected is shown in Appendix H together with the best fitted curve and expression of each set of data. In table 5.10, loading time at each supply source are collected.

Unit: minutes

Loading Operation	Expression
Rail loading time at BRP	UNIF (303, 33)
Truck loading time at BRP	UNIF (44.5, 4.5)
Truck loading time at GSP LKB	NORM (54.3, 2.58)

Table 5.10: Loading Time

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.4.2.5 Unloading Time

Unloading time is collected from the working record of the destination depots. Raw data and Best fitted curve and expression of the unloading time is gathered shown in Appendix I. In table 5.11, rail and truck unloading time are addressed.

Unit: minutes

	Expression
Rail unloading time	NORM (486, 33.6)
Truck unloading	UNIF (59.5, 4.5)

Table 5.11: Unloading Time

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

5.5 Build the Based Line Model

Simulation model of the LPG distribution system will be built up by using ProModel*PC* version 5.01. The LPG simulation model going to be constructed will be based upon an initial solution provided by the LP model addressed in Chapter 4. Entities in the system and also their interaction are constructed according to the details stated in an activity cycle diagram. Computer command and also any explanation about the model are addressed in Appendix J.

5.6 Validate the Model

As mentioned in Chapter 2, a number of steps were taken to verify that the model works as intended and to validate that its operation mimics the reality. The following issues are conducted to prove the model.

5.6.1 Building the Model with ProModel*PC*

The base line models was developed and executed using ProModel *PC* 5.01. With its easy-to-use, not much programming skill is required in constructing the model. It automatically translates the user's requirement into a computer simulation language which significantly reduces the likelihood of logical errors. In building the model, ProModel*PC* automatically guides the user through the complete model building by a helping hand of fill-in-the-blank prompts. Automatic data editing and error checking feature make certain that all model information is consistent and complete, ProModel*PC* User's Guide (1993). Moreover, its graphical user interface helps the modeler visualize what is happening during a simulation. This animation provides a basis for verification of a model's operation.

5.6.2 Comparison the Model's Result with those of the Real Event

In order to ensure that the base line model is good enough to present real situation. Comparison the model's result with those of the real event is another way to make certain. Again March, 2000 will be used as a case study. Primary result of the base line model as of March, 2000 is shown in appendix K. Real activities occurred in March, 2000 are illustrated in table 5.12. In table

5.13, the results achieved from the base line model are addressed. For a comparison, table 5.14 is provided for this purpose.

LPG DISTRIBUTION PLAN AS OF MARCH'2000

KONKHAEN

Date	Open Inventory Plan	Open Inventory Actual	Demand Plan	Demand Actual S/S	Demand Actual Total	Supply (Rail) Plan	Supply (Rail) Actual
1	1200	1478	600	383	616	458	458
2	1058	1313	600	237	477	458	458
3	916	1288	600	345	591	458	458
4	774	1157	600	170	477	916	916
5	1090	1592	0	0	0	458	0
6	1548	1589	600	446	779	458	916
7	1406	1727	600	456	812	458	458
8	1264	1371	600	286	572	916	458
9	1580	1257	600	345	564	458	458
10	1438	1148	600	305	572	458	458
11	1296	1034	600	248	569	458	458
12	1154	923	0	0	0	458	458
13	1612	1390	600	456	746	458	458
14	1470	1095	600	273	538	458	458
15	1328	1010	600	300	540	458	458
16	1186	929	600	351	622	916	916
17	1502	1220	600	270	489	458	0
18	1360	738	600	255	529	458	916
19	1218	1117	0	0	0	458	458
20	1676	1582	600	453	723	458	458
21	1534	1314	600	240	485	458	458
22	1392	1282	600	336	584	916	916
23	1708	1614	600	257	483	458	458
24	1566	1598	600	327	584	458	458
25	1424	1468	600	159	462	458	458
26	1282	1473	0	0	0	458	458
27	1740	1939	600	378	710	458	458
28	1598	1673	600	362	584	458	458
29	1456	1542	600	285	521	458	458
30	1314	1478	600	255	505	458	458
31	1172	1428	600	362	567	916	916
1	1488	Total	16200	8540	15701	16488	16030

LAMPANG

Date	Open Inventory Plan	Open Inventory Actual	Demand Plan	Demand Actual S/S	Demand Actual Total	Supply Plan Rail	Supply Plan LKB	Supply Plan BRP	Supply Plan Total	Supply Actual Rail	Supply Actual LKB	Supply Actual BRP
1	1300	1405	467	241	452		295	80	375		293	116
2	1208	1359	467	263	443		295	80	375		306	94
3	1116	1317	467	240	457		295	80	375		285	95
4	1024	1236	467	211	415		295	80	375		314	85
5	932	1218	0	0	0		295	80	375		270	57
6	1307	1554	467	285	521		295	80	375		270	0
7	1215	1295	467	265	507		295	80	375		283	85
8	1123	1154	467	270	472		295	80	375		298	85
9	1031	1064	467	235	421		295	80	375		283	87
10	939	1011	467	252	454	458	295	80	833		239	100
11	1305	896	467	269	498		295	80	375	407	284	103
12	1213	1188	0	0	0		295	80	375		321	94
13	1588	1611	467	262	498		295	80	375		247	0
14	1496	1357	467	261	455		295	80	375		263	100
15	1404	1263	467	270	471		295	80	375		315	79
16	1312	1162	467	206	385		295	80	375		271	103
17	1220	1171	467	243	418		295	80	375		287	87
18	1128	1127	467	246	486		295	80	375		286	71
19	1036	996	0	0	0		295	80	375		285	71
20	1411	1360	467	236	445		295	80	375		271	0
21	1319	1180	467	286	531		295	80	375		271	99
22	1227	1015	467	218	395		295	80	375		323	85
23	1135	1027	467	211	425		295	80	375		277	86
24	1043	964	467	225	384	458	295	80	833		300	100
25	1409	980	467	260	468		295	80	375	458	308	86
26	1317	1361	0	0	0		295	80	375		271	85
27	1692	1725	467	207	457		295	80	375		352	0
28	1600	1620	467	241	478		295	80	375		330	100
29	1508	1571	467	221	421		295	80	375		315	94
30	1416	1559	467	288	440		295	80	375		307	86
31	1324	1510	467	242	437		295	80	375		306	101
1	1232	Total	12609	6654	12234	916	9145	2480	12541	865	9027	2433

NAKORNSAWAN

Date	Open Inventory Plan	Open Inventory Actual	Demand Plan	Demand Actual S/S	Demand Actual Total	Supply Plan Rail	Supply Plan LKB	Supply Plan BRP	Supply Plan Total	Supply Actual Rail	Supply Actual LKB	Supply Actual BRP
1	1000	961	393	130	288	510			510	510		
2	1117	1237	393	180	340	510			510	510		
3	1234	1406	393	208	377	510			510	510		
4	1351	1539	393	186	337				0			
5	958	1201	0	0	0	510			510	510		
6	1468	1712	393	230	425	510			510			
7	1585	1285	393	240	414	510			510	510		
8	1702	1380	393	182	337				0	510		
9	1309	1552	393	247	417	510			510	510		
10	1426	1647	393	190	381				0			
11	1033	1258	393	214	406	510			510			
12	1150	849	0	0	0				0	510		
13	1150	1359	393	274	428	510			510	510		
14	1267	1441	393	223	388	510			510	510		
15	1384	1564	393	232	415	510			510	510		
16	1501	1658	393	240	408				0			
17	1108	1247	393	169	332	510			510	510		
18	1225	1422	393	150	345	510			510	510		
19	1342	1604	0	0	0				0			
20	1342	1604	393	222	409	510			510	510		
21	1459	1687	393	172	306	510			510	510		
22	1576	1881	393	157	358				0			
23	1183	1525	393	168	351	510			510			
24	1300	1171	393	205	349				0			
25	907	817	393	171	349	510			510			
26	1024	468	0	0	0				0	510		
27	1024	976	393	202	368	510			510	510		
28	1141	1113	393	197	379	510			510	510		
29	1258	1254	393	166	356	510			510	510		
30	1375	1410	393	184	339	510			510	510		
31	1492	1578	393	214	364				0			
1	1099	Total	10611	5353	9966	10710	0	0	10710	10200	20910	0

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Table 5.12: Real LPG Distribution System as of March, 2000 for KKN, LMP, and NSW

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

March 2000		Replication 1	Replication 2	Replication 3	Average
	Rail	4	4	4	4
Transporter	Truck in BRP fleet	19	19	19	19
	Truck in LKB fleet	23	23	23	23
Number of	Truck from LKB	0	0	0	-
transportation	Truck from BRP	0	0	0	-
trips to	Rail	36	35	35	35
KKN	Total truck	0	0	0	-
Number of	Truck from LKB	576	589	602	589
transportation	Truck from BRP	158	158	164	160
trips to	Rail	2	2	2	2
LMP	Total truck	734	747	766	749
Number of	Truck from LKB	0	0	0	-
transportation	Truck from BRP	3	0	6	3
trips to	Rail	20	21	21	21
NSW	Total truck	3	0	6	3
	avg.	1,097	1,205	1,078	1126.67
KKN	min.	466	515	370	450.33
Opening Stock	Number of shortage	0	0	0	0.00
	Max. Shortage hour	0	0	0	0.00
	Total shortage hour	0	0	0	0.00
	avg.	1,065	1,209	1,125	1133.00
LMP	min.	520	631	491	547.33
Opening Stock	Number of shortage	0	0	0	0.00
	Max. Shortage hour	0	0	0	0.00
	Total shortage hour	0	0	0	0.00
	avg.	1,222	1,254	1,209	1228.33
NSW	min.	306	525	59	296.67
Opening Stock	Number of shortage	0	0	0	0.00
	Max. Shortage hour	0	0	0	0.00
	Total shortage hour	0	0	0	0.00
	KKN	16,420	15,888	16,191	16,166.33
Sales	LMP	12,485	12,358	12,566	12,469.67
	NSW	10,115	10,245	10,701	10,353.67
	Rail loading@BRP	39.88	39.37	38.94	39.40
	Truck loading@BRP	8.05	7.91	8.41	8.12
	Truck loading@LKB	17.89	17.91	17.89	17.90
	Rail unloading@KKN	37.88	36.91	36.73	37.17
	Rail unloading@LMP	2.18	2.25	2.16	2.20
Resource	Rail unloading@NSW	21.16	21.64	23.32	22.04
Utilization	Truck unloading@KKN	0.00	0.00	0.00	0.00
	Truck unloading@LMP	32.96	33.05	33.18	33.06
	Truck unloading@NSW	0.20	0.00	0.40	0.20
	Rail	63.89	63.21	63.83	63.64
	Truck in BRP fleet	28.52	28.34	29.83	28.90
	Truck in LKB fleet	32.75	32.95	32.78	32.83

Table 5.13: The Base Line Model's Result as of March, 2000

March 2000		Actual	Simulation	% Difference
Transporter	Rail	4	4	0.00
	Truck in BRP fleet	22	19	-13.64
	Truck in LKB fleet	23	23	0.00
Number of transportation trips to KKN	Truck from LKB	0	0	0.00
	Truck from BRP	0	0	0.00
	Rail	34	35	3.92
	Total truck	0	0	0.00
Number of transportation trips to LMP	Truck from LKB	564	589	4.43
	Truck from BRP	153	160	4.58
	Rail	2	2	0.00
	Total truck	717	749	4.46
Number of transportation trips to NSW	Truck from LKB	0	0	0.00
	Truck from BRP	0	3	N/A
	Rail	21	21	0.00
	Total truck	0	3	N/A
KKN Opening Stock	avg.	1,347	1,127	-16.36
	min.	738	450	-38.98
	Number of shortage	0	0	0.00
	Max. Shortage hour	0	0	0.00
	Total shortage hour	0	0	0.00
LMP Opening Stock	avg.	1,266	1,133	-10.51
	min.	896	547	-38.91
	Number of shortage	0	0	0.00
	Max. Shortage hour	0	0	0.00
	Total shortage hour	0	0	0.00
NSW Opening Stock	avg.	1,349	1,228	-8.94
	min.	468	297	-36.61
	Number of shortage	0	0	0.00
	Max. Shortage hour	0	0	0.00
	Total shortage hour	0	0	0.00
Sales	KKN	15,701	16,166	2.96
	LMP	12,234	12,470	1.93
	NSW	9,966	10,354	3.89
Resource Utilization	Rail loading@BRP	N/A	39.40	N/A
	Truck loading@BRP	N/A	8.12	N/A
	Truck loading@LKB	N/A	17.90	N/A
	Rail unloading@KKN	N/A	37.17	N/A
	Rail unloading@LMP	N/A	2.20	N/A
	Rail unloading@NSW	N/A	22.04	N/A
	Truck unloading@KKN	N/A	0.00	N/A
	Truck unloading@LMP	N/A	33.06	N/A
	Truck unloading@NSW	N/A	0.20	N/A
	Rail	N/A	63.64	N/A
	Truck in BRP fleet	N/A	28.90	N/A
	Truck in LKB fleet	N/A	32.83	N/A

Table 5.14: A Comparison between the Base Line Model's Result and that of the Real Operation

From table 5.14, the result achieved from the two sources is slightly different. From the experience of the operator, it can be said that the result of the simulation model is acceptable. The reason why the result of the simulation deviates from the actual case can be explained as follows:

- Number of trucks required in both BRP fleet and GSP LKB fleet is different because the number of trucks used in actual operation is the actual total number of truck that PTT has (45 trucks) which slightly exceeds the exact requirement while the simulation defines the exact requirement. It means that in March, 2000, some trucks are idle which is synchronize with the fact informed by the truck contractor, SC Management Co., Ltd.

- Number of rail sent to KKN from simulation is greater than that of the actual case by 1 rail. It is because the total sale from the simulation is greater than the actual sales by 465 tons or approximately 1 rail (458 tons).

- Number of trucks transportation trips sent to LMP is approximately 4% difference or 1 trip per day which is a very little difference. One reason why the trips from the simulation is slightly higher than that of the actual situation is that the simulation demand is about 2 % higher than that of the real one. Moreover, this can be caused by a fluctuation in daily demand as well.

- For the entire month of simulation, there are 3 trucks sent for BRP to NSW while in real operation, no trucks are sent. It could be explained that in building a computer language, everything can be defined as 0 or 1, YES or NO only. There is no trade-off between these 2 sets of solutions. 3 trucks in 1 month is very little number in sense of real operation. With a judgement of the operator in real situation, for a case like this, truck may not be sent. However, working with computer which has no flexibility or judgement like that of the human. Therefore, it is possible for this event to occur.

- Total monthly demands of the simulation are slightly different from those of the real cases which are acceptable.

- As a result of a fluctuation in demand, average opening and minimum stock as of the simulation differ from those of the real event within the reasonable range.

From all the explanation about the causes of the difference between the result of the simulation model and what actually happen, it can be said that the base line model can be relied on.

5.6.3 Statistical Testing

In order to ensure that the transportation data obtained from the simulation model is good enough to be a representative of the real situation, a statistical testing is then applied to achieve this purpose.

The average value of each set of transportation results obtained from the simulation model will be tested to identify whether it is equal to that of the real situation. This statistical testing will be applied only with an item that creates a difference between the result of the simulation model and the result of the actual operation, number of rail transportation trips sent to KKN, number of truck transportation trips sent from GSP LKB to LMP, number of truck transportation trips sent from BRP to LMP, and number of truck transportation trips sent from BRP to NSW. Normal distribution is assumed throughout the test. Since there are only 3 samples for each case, Student's t-test will be used in testing. The following table is a summary of all the data that is going to be tested.

Unit: trips

	Simulation					Actual
	Rep. 1	Rep. 2	Rep. 3	Average	Std. Dev.	
Rail sent to KKN	36	35	35	35	0.47	34
Truck from LKB sent to LMP	576	589	602	589	10.61	564
Truck from BRP sent to LMP	158	158	164	160	2.83	153
Truck from BRP sent to NSW	3	-	6	3	2.45	-

Table 5.15: Data Summary for Statistical Testing

A statistical testing of each issue is illustrated as follows:

1. Number of rail transportation trips sent to KKN

Two tailed test

H_0: There is no difference between the population mean of the number of rail transportation trips sent to KKN obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0). ($\mu_1 = \mu_0$)

H_1: The population mean of the number of rail transportation trips sent to KKN obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0) are different. ($\mu_1 \neq \mu_2$)

Significant level: 95% confidence (α = 0.025 at one tailed)

Test Statistic

$$u = \frac{(\overline{x}_1 - \mu_0)}{(\sigma\text{^} / \sqrt{n})}$$

where x_1 = Arithmetic mean of the number of rail transportation trips sent to KKN obtained from the simulation = 35

μ_0 = The number of rail transportation trips sent to KKN obtained from the real operation = 34

$\hat{\sigma}$ = Best estimate of a standard deviation of the number of rail transportation trips sent to KKN obtained from the simulation = 0.47

n = sample size of the simulation = 3

Degree of freedom of the simulation

ν = n -1

where ν = Degree of freedom of the simulation

n = Sample size of the simulation = 3

Thus,

ν = 3 –1 = 2

Substitute all the values above into the equation of the test statistic.

Thus,

u = 3.685

From the percentage points of the t-Distribution Table

when ν = 2, 5% significant level

$t_{0.025,\,2}$ = 4.303

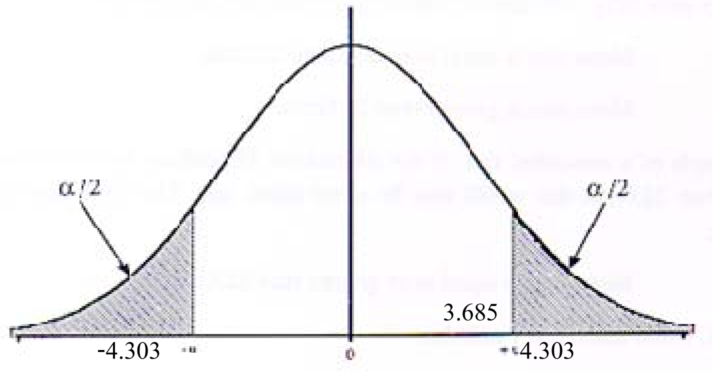

Figure 5.8: The Percentage Points of the T Distribution for Rail Sent to KKN Testing

Conclusion

H_0 cannot be rejected at 95% confidence. There is no significant difference between the population mean of the number of rail transportation trips sent to KKN obtained from the simulation and the number obtained from the real operation.

2. Number of truck transportation trips sent from LKB to LMP

Two tailed test

H_0: There is no difference between the population mean of the number of truck transportation trips sent from GSP LKB to LMP obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0). ($\mu_1 = \mu_0$)

H_1: The population mean of the number of truck transportation trips sent from GSP LKB to LMP obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0) are different. ($\mu_1 \neq \mu_2$)

Significant level: 95% confidence (α = 0.025 at one tailed)

Test Statistic

$$u = \frac{(\bar{x}_1 - \mu_0)}{(\hat{\sigma} / \sqrt{n})}$$

where x_1 = Arithmetic mean of the number of truck transportation trips sent from GSP LKB to LMP obtained from the simulation = 589

μ_0 = The number of truck transportation trips sent from GSP LKB to LMP obtained from the real operation = 564

$\hat{\sigma}$ = Best estimate of a standard deviation of the number of truck transportation trips sent from GSP LKB to LMP obtained from the simulation = 10.61

n = sample size of the simulation = 3

Degree of freedom of the simulation

$\nu = n - 1$

where ν = Degree of freedom of the simulation

n = Sample size of the simulation = 3

Thus,

$\nu = 3 - 1 = 2$

Substitute all the values above into the equation of the test statistic.

Thus,

$u = 4.081$

From the percentage points of the t-Distribution Table when ν = 2, 5% significant level

$t_{0.025, 2}$ = 4.303

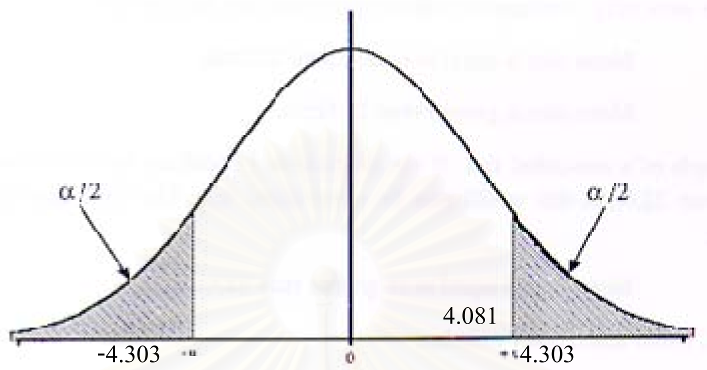

Figure 5.9: The Percentage Points of the T Distribution for Truck Sent from LKB to LMP Testing

Conclusion

H_0 cannot be rejected at 95% confidence. There is no significant difference between the population mean of the number of truck transportation trips sent from GSP LKB to LMP obtained from the simulation and the number obtained from the real operation.

3. Number of truck transportation trips sent from BRP to LMP

Two tailed test

H_0: There is no difference between the population mean of the number of truck transportation trips sent from BRP to LMP obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0). ($\mu_1 = \mu_0$)

H_1: The population mean of the number of truck transportation trips sent from BRP to LMP obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0) are different. ($\mu_1 \neq \mu_2$)

Significant level: 95% confidence (α = 0.025 at one tailed)

Test Statistic

$$u = \frac{(\overline{x_1} - \mu_0)}{(\sigma\text{^} / \sqrt{n})}$$

where x_1 = Arithmetic mean of the number of truck transportation trips sent from BRP to LMP obtained from the simulation = 160

μ_0 = The number of truck transportation trips sent from BRP to LMP obtained from the real operation = 153

σ^= Best estimate of a standard deviation of the number of truck transportation trips sent from BRP to LMP obtained from the simulation = 2.83

n = sample size of the simulation = 3

Degree of freedom of the simulation

ν = n -1

where ν = Degree of freedom of the simulation

n = Sample size of the simulation = 3

Thus,

ν = 3 –1 = 2

Substitute all the values above into the equation of the test statistic.

Thus,

$u \quad = 4.284$

From the percentage points of the t-Distribution Table

when $\quad \nu \quad = 2, \quad$ 5% significant level

$t_{0.025,\, 2} \quad = 4.303$

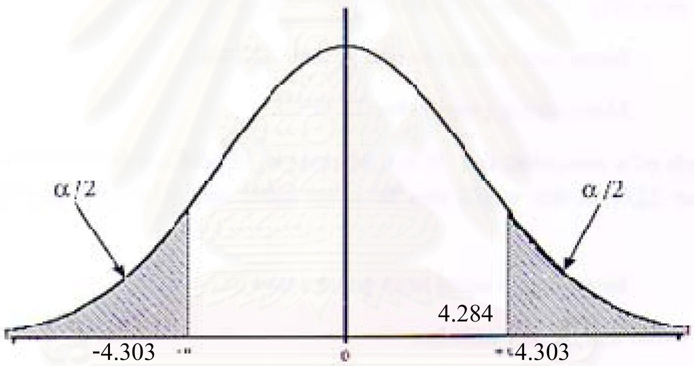

Figure 5.10: The Percentage Points of the T Distribution for Truck Sent from BRP to LMP Testing

Conclusion

H_0 cannot be rejected at 95% confidence. There is no significant difference between the population mean of the number of truck transportation trips sent from BRP to LMP obtained from the simulation and the number obtained from the real operation.

4. Number of truck transportation trips sent from BRP to NSW

Two tailed test

H_0: There is no difference between the population mean of the number of truck transportation trips sent from BRP to NSW obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0). ($\mu_1 = \mu_0$)

H_1: The population mean of the number of truck transportation trips sent from BRP to NSW obtained from the simulation (μ_1) and the number obtained from the real operation (μ_0) are different. ($\mu_1 \neq \mu_2$)

Significant level: 95% confidence (α = 0.025 at one tailed)

Test Statistic

$$u = \frac{(\overline{x}_1 - \mu_0)}{(\sigma\hat{}/\sqrt{n})}$$

where x_1 = Arithmetic mean of the number of truck transportation trips sent from BRP to NSW obtained from the simulation = 3

μ_0 = The number of truck transportation trips sent from BRP to NSW obtained from the real operation = 0

$\sigma\hat{}$= Best estimate of a standard deviation of the number of truck transportation trips sent from BRP to NSW obtained from the simulation = 2.45

n = sample size of the simulation = 3

Degree of freedom of the simulation

ν = n -1

where ν = Degree of freedom of the simulation

n = Sample size of the simulation = 3

Thus,

ν = 3 –1 = 2

Substitute all the values above into the equation of the test statistic.

Thus,

u = 2.120

From the percentage points of the t-Distribution Table

when ν = 2, 5% significant level

$t_{0.025, 2}$ = 4.303

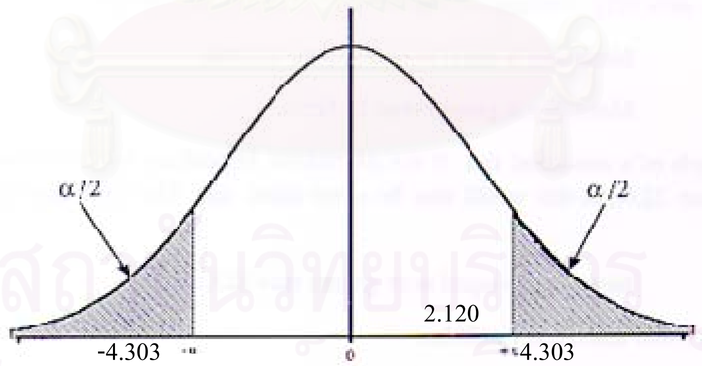

Figure 5.11: The Percentage Points of the T Distribution for Truck Sent from BRP to NSW Testing

Conclusion

H_0 cannot be rejected at 95% confidence. There is no significant difference between the population mean of the number of truck transportation trips sent from BRP to NSW obtained from the simulation and the number obtained from the real operation.

From the statistical testing presented above, all the H_0 cannot be rejected at 95% confidence. It can be said that there is no difference between the result obtained from the simulation and that of the actual operation at 95% confidence. Consequently, it can be concluded that the simulation model constructed is good enough to mimic the real system and can be further applied in the next step of this study.

5.6.4 Face Validity

By taking the advantage of the graphical user interface, the model is test by the operators who are familiar with the real LPG distribution operation. It is found that the model's animated behavior accurately mimics the situations of the real system.

5.7 Perform Running the Model

5.7.1 Steps of Running the Model

The purpose of running the simulation model is to figure out the suitable number of transporters required in operating the LPG distribution system. The number of transporters as a result of the simulation model is the amount of transporters that makes the overall characteristics of the distribution system meet all the criteria addressed.

Running the model can be performed by the following steps:

- Put a set of inputs into the base line model. Set of inputs consists of the following items:

  - Number of rail and trucks guided by the LP model
  - Monthly demand of each depot
  - Number of total days and working days in that month
  - etc.

- Run the model

- Obtain and initially analyze the result. If the result is not acceptable according to the criteria established, the number of transporters required will be adjusted until the result of the simulation model is practical.

As previously discussed in Chapter 4, the first new rail can join the system no prior to the beginning of the year 2004 because a procurement period takes at least 3 years. Therefore, the LPG distribution plan as of 2001 through 2003 will be run by using the fix number of rails, 4 rails. For the year 2004 and 2005, rail will be added into the system one by one until the total number of rail in the system is equal to the boundary number guided by the LP model in order to find the optimal solution for the 5-year-distribution plan. From the LP model, by not concerning about the investment allocation, 7.96 and 8.51 rails are required in year 2004 and 2005 respectively. Consequently, for the year 2004, the model will be run with 4, 5, 6, 7, and 8 rails and for the year 2005, the model will be run with 4, 5, 6, 7, 8, and 9 rails. Lastly, the simulation result together with the investment allocation of each case will be compared to figure out the optimal solution for the system.

5.7.2 Criteria Used in Accepting the Simulation Result

In order to accept the number of transporters required as a result of the simulation, the following characteristics according to the management policy must be achieved.

- The number of shortage should not exceed 2 times per month for each depot.
- The longest shortage hour should be longer than 3 hours.
- The total period of shortage hours should not exceed 5 hours.
- The survival days without supply of the average opening inventory should be approximately at least 1 day.

5.8 Obtain the Simulation Result

In order to find out the optimal solution, the total transportation cost will be used as criteria together with the investment allocation. However, the total transportation cost obtained from the simulation result cannot be used immediately because these total transportation costs are based on different quantity of the total transportation volume. The total transportation volume in each simulation case varies as a result of fluctuation in demand like those of the real world operation. Consequently, the average transportation cost may give more practical characteristic for a comparison purpose. The average transportation cost per unit volume will be multiply with the total demand according to the plan to figure out the total transportation volume that are based on the same basis for each proposed case. The average transportation cost per unit volume of each case are addressed in table 5.16. These primary data will be further analyzed in the next part, 5.9 Analysis the Result.

Year	Total Volume Transported (tons)	Total Transportation Cost (baht)	Average Transportation Cost per Unit Volume (baht/ton)
2001	517,268	379,331,789	733.337
2002	551,728	432,490,285	783.883
2003	582,144	478,256,261	821.543

Year 2004	Total Volume Transported (tons)	Total Transportation Cost (baht)	Average Transportation Cost per Unit Volume (baht/ton)
4 Rails	612,086	527,388,390	861.625
5 Rails	614,512	464,448,378	755.800
6 Rails	607,014	388,933,974	640.733
7 Rails	614,718	357,755,534	581.983
8 Rails	622,828	357,783,914	574.451

Year 2005	Total Volume Transported (tons)	Total Transportation Cost (baht)	Average Transportation Cost per Unit Volume (baht/ton)
4 Rails	644,054	576,857,145	895.666
5 Rails	652,776	525,009,829	804.273
6 Rails	636,206	434,695,809	683.263
7 Rails	646,288	382,019,037	591.097
8 Rails	655,126	377,664,345	576.476
9 Rails	655,854	376,362,025	573.850

Table 5.16: Average Total Transportation Cost per Unit Volume as a Result of the Simulation Model

5.9 Analysis the Result

In order to figure out the optimal solution the results obtained from the simulation model must be analyzed in details. The criteria used in selecting the most suitable case is the transportation cost and the investment in buying rail. This expense will be calculated based on cash basis. The case that has the minimum expense will be selected.

As previously described in part 5.8, the total transportation cost initially achieved from the model is based on the different transportation volume due to the fluctuation of the demand designed in the model. Hence, the average total transportation cost will be used in the further analysis to generate more practical solution. In order to calculate the total transportation cost based on the same transportation volume, the average total transportation cost will be multiplied with the total demand according to the forecasted plan as shown in table 5.17.

Year	Planned Volume (tons)	Average Transportation Cost per Unit Volume (baht/ton)	Total Transportation Cost (baht)
2001	485,300	733.337	355,888,470
2002	516,300	783.883	404,718,872
2003	547,000	821.543	449,383,958

Year 2004	Planned Volume (tons)	Average Transportation Cost per Unit Volume (baht/ton)	Total Transportation Cost (baht)
4 Rails	577,500	861.625	497,588,240
5 Rails	577,500	755.800	436,474,696
6 Rails	577,500	640.733	370,023,377
7 Rails	577,500	581.983	336,095,284
8 Rails	577,500	574.451	331,745,218

Year 2005	Planned Volume (tons)	Average Transportation Cost per Unit Volume (baht/ton)	Total Transportation Cost (baht)
4 Rails	608,800	895.666	545,281,342
5 Rails	608,800	804.273	489,641,139
6 Rails	608,800	683.263	415,970,312
7 Rails	608,800	591.097	359,859,985
8 Rails	608,800	576.476	350,958,523
9 Rails	608,800	573.850	349,360,072

Table 5.17: Total Transportation Cost According to the Planned Demand

In order to select the optimal solution, the total transportation cost shown in table 5.17 is not sufficient. Cost allocation of the rail investment must be inevitably concerned.

As mentioned in Chapter 3, 1 rail (18 bogies) cost 109,998,000 baht or approximately 110,000,000 baht. The following assumptions are assumed in doing the investment allocation.

- Rail price: 110,000,000 baht per rail (constant)
- Usage life: 5 years
- Investment allocation: 22,000,000 per year

In order to answer the question of how many rails and also when each rail should be bought, various policies of buying rails are proposed as alternatives. Table 5.18 shows a trend of the total transportation cost when rail is added one by one. From table 5.18, it is obvious that a saving transportation cost per rail reduces when there are too many rails in the system. In other words, too many rails may not be worthwhile. For example, in 2004, the total transportation cost in the case of 4 rails is greater than the total transportation cost in the case of 5 rails by 61,113,544 baht. For the difference between the case of 7 rails and the case of 8 rails, the total transportation cost in the case of 7 rails is greater than that of the case of 8 rails by 4,350,067 baht. It is clear that only a little amount of money can be saved, 4,350,067 baht, when the total number of rails in the system is increased from 7 rails to 8 rails. Obviously, 8 rails in the year 2004 may be too high investment. Consequently, only some possible cases are proposed as alternatives for this purpose.

Year 2004	Total transportation cost (baht)	Saving per rail (baht)
8 Rails	331,745,218	4,350,067
7 Rails	336,095,284	33,928,093
6 Rails	370,023,377	66,451,319
5 Rails	436,474,696	61,113,544
4 Rails	497,588,240	-

Year 2005	Total transportation cost (baht)	Saving per rail (baht)
9 Rails	349,360,072	1,598,451
8 Rails	350,958,523	8,901,462
7 Rails	359,859,985	56,110,328
6 Rails	415,970,312	73,670,826
5 Rails	489,641,139	55,640,204
4 Rails	545,281,342	-

Table 5.18: Saving in Total Transportation Cost when Rail is Increased

Consequently, following cases are proposed as the alternative.

- Case 1: Add 1 Rail at the beginning of the year 2004
- Case 2: Add 1 Rail at the beginning of the year 2004 and 1 Rail at the beginning of the year 2005
- Case 3: Add 2 Rails at the beginning of the year 2004
- Case 4: Add 1 Rail at the beginning of the year 2004 and 2 Rails at the beginning of the year 2005
- Case 5: Add 2 Rails at the beginning of the year 2004 and 1 Rail at the beginning of the year 2005
- Case 6: Add 3 Rails at the beginning of the year 2004
- Case 7: Add 1 Rail at the beginning of the year 2004 and 3 Rails at the beginning of the year 2005

- Case 8: Add 2 Rails at the beginning of the year 2004 and 2 Rails at the beginning of the year 2005
- Case 9: Add 3 Rails at the beginning of the year 2004 and 1 Rail at the beginning of the year 2005
- Case 10: Add 4 Rails at the beginning of the year 2004
- Case 11: No Rail is Added (the present management policy)

The details of each proposed case will be divided into 3 main areas: Total transportation cost, Investment Allocation, and Total cost. Details of the total transportation cost can be found in table 5.17. The investment allocation of buying rail will be allocated according to the assumption previously mentioned. For the total cost, it will be calculated from the total transportation cost and the investment allocation. The interest rate is assumed to be 8.50% per year. Details of each case can be illustrated as follows:

1. Case 1Add 1 Rail at the beginning of the year 2004

1.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	436,474,696
2005	489,641,139

1.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	0	0	0	22,000,000
2005	22,000,000	0	0	0	22,000,000
2006	22,000,000	0	0	0	22,000,000
2007	22,000,000	0	0	0	22,000,000
2008	22,000,000	0	0	0	22,000,000
2009	0	0	0	0	0

1.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	436,474,696	22,000,000	458,474,696	1.386	330,823,551
2005	489,641,139	22,000,000	511,641,139	1.504	340,264,598
				Total	1,694,712,880

2. Case 2Add 1 Rail at the beginning of the year 2004 and 1 Rail at the beginning of the year 2005

2.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	436,474,696
2005	415,970,312

2.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	0	0	0	22,000,000
2005	22,000,000	22,000,000	0	0	44,000,000
2006	22,000,000	22,000,000	0	0	44,000,000
2007	22,000,000	22,000,000	0	0	44,000,000
2008	22,000,000	22,000,000	0	0	44,000,000
2009	0	22,000,000	0	0	22,000,000

2.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	436,474,696	22,000,000	458,474,696	1.386	330,823,551
2005	415,970,312	44,000,000	459,970,312	1.504	305,901,151
				Total	1,660,349,434

3. Case 3Add 2 Rails at the beginning of the year 2004

3.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	370,023,377
2005	415,970,312

3.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	22,000,000	0	0	44,000,000
2005	22,000,000	22,000,000	0	0	44,000,000
2006	22,000,000	22,000,000	0	0	44,000,000
2007	22,000,000	22,000,000	0	0	44,000,000
2008	22,000,000	22,000,000	0	0	44,000,000
2009	0	0	0	0	0

3.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	370,023,377	44,000,000	414,023,377	1.386	298,748,622
2005	415,970,312	44,000,000	459,970,312	1.504	305,901,151
				Total	1,628,274,505

4. Case 4Add 1 Rail at the beginning of the year 2004 and 2 Rails at the beginning of the year 2005

4.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	436,474,696
2005	359,859,985

4.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	0	0	0	22,000,000
2005	22,000,000	22,000,000	22,000,000	0	66,000,000
2006	22,000,000	22,000,000	22,000,000	0	66,000,000
2007	22,000,000	22,000,000	22,000,000	0	66,000,000
2008	22,000,000	22,000,000	22,000,000	0	66,000,000
2009	0	22,000,000	22,000,000	0	44,000,000

4.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	436,474,696	22,000,000	458,474,696	1.386	330,823,551
2005	359,859,985	66,000,000	425,859,985	1.504	283,216,234
				Total	1,637,664,516

5. Case 5 Add 2 Rails at the beginning of the year 2004 and 1 Rail at the beginning of the year 2005

5.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	370,023,377
2005	359,859,985

5.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	22,000,000	0	0	44,000,000
2005	22,000,000	22,000,000	22,000,000	0	66,000,000
2006	22,000,000	22,000,000	22,000,000	0	66,000,000
2007	22,000,000	22,000,000	22,000,000	0	66,000,000
2008	22,000,000	22,000,000	22,000,000	0	66,000,000
2009	0	0	22,000,000	0	22,000,000

5.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	370,023,377	44,000,000	414,023,377	1.386	298,748,622
2005	359,859,985	66,000,000	425,859,985	1.504	283,216,234
				Total	1,605,589,588

6. Case 6 Add 3 Rails at the beginning of the year 2004

6.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	336,095,284
2005	359,859,985

6.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	22,000,000	22,000,000	0	66,000,000
2005	22,000,000	22,000,000	22,000,000	0	66,000,000
2006	22,000,000	22,000,000	22,000,000	0	66,000,000
2007	22,000,000	22,000,000	22,000,000	0	66,000,000
2008	22,000,000	22,000,000	22,000,000	0	66,000,000
2009	0	0	0	0	0

6.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	336,095,284	66,000,000	402,095,284	1.386	290,141,617
2005	359,859,985	66,000,000	425,859,985	1.504	283,216,234
				Total	1,596,982,583

7. Case 7 Add 1 Rail at the beginning of the year 2004 and 3 Rails at the beginning of the year 2005

7.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	436,474,696
2005	350,958,523

7.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	0	0	0	22,000,000
2005	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2006	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2007	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2008	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2009	0	22,000,000	22,000,000	22,000,000	66,000,000

7.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	436,474,696	22,000,000	458,474,696	1.386	330,823,551
2005	350,958,523	88,000,000	438,958,523	1.504	291,927,357
				Total	1,646,375,639

8. Case 8 Add 2 Rails at the beginning of the year 2004 and 2 Rails at the beginning of the year 2005

8.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	370,023,377
2005	350,958,523

8.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	22,000,000	0	0	44,000,000
2005	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2006	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2007	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2008	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2009	0	0	22,000,000	22,000,000	44,000,000

8.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	370,023,377	44,000,000	414,023,377	1.386	298,748,622
2005	350,958,523	88,000,000	438,958,523	1.504	291,927,357
				Total	1,614,300,710

9. Case 9 Add 3 Rails at the beginning of the year 2004 and 1 Rail at the beginning of the year 2005

9.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	336,095,284
2005	350,958,523

9.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	22,000,000	22,000,000	0	66,000,000
2005	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2006	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2007	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2008	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2009	0	0	0	22,000,000	22,000,000

9.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	336,095,284	66,000,000	402,095,284	1.386	290,141,617
2005	350,958,523	88,000,000	438,958,523	1.504	291,927,357
				Total	1,605,693,706

10. Case10 Add 4 Rails at the beginning of the year 2004

10.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	331,745,218
2005	350,958,523

10.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2005	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2006	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2007	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2008	22,000,000	22,000,000	22,000,000	22,000,000	88,000,000
2009	0	0	0	0	0

10.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	331,745,218	88,000,000	419,745,218	1.386	302,877,355
2005	350,958,523	88,000,000	438,958,523	1.504	291,927,357
				Total	1,618,429,444

11. Case11 No rail is added (The Present Management Policy)

11.1 Total Transportation Cost (baht)

Year	Transportation Cost
2001	355,888,470
2002	404,718,872
2003	449,383,958
2004	497,588,240
2005	545,281,342

11.2 Investment Allocation (baht)

Year	Investment Allocation (at the end of each year)				
	Rail#1	Rail#2	Rail#3	Rail#4	Total
2001	0	0	0	0	0
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
2006	0	0	0	0	0
2007	0	0	0	0	0
2008	0	0	0	0	0
2009	0	0	0	0	0

11.3 Total cost (baht) **(present value)**

Year	Transportation Cost	Investment Allocation	Total Cost	Interest Factor	Present Value
2001	355,888,470	0	355,888,470	1.085	328,007,806
2002	404,718,872	0	404,718,872	1.177	343,790,586
2003	449,383,958	0	449,383,958	1.277	351,826,340
2004	497,588,240	0	497,588,240	1.386	359,046,878
2005	545,281,342	0	545,281,342	1.504	362,636,861
				Total	1,745,308,471

Result of the total cost of each case can be summarized again shown in table 5.19.

Case	**Total Cost** (baht)	**Rank**
1	1,694,712,880	10
2	1,660,349,434	9
3	1,628,274,505	6
4	1,637,664,516	7
5	1,605,589,588	2
6	***1,596,982,583***	***1***
7	1,646,375,639	8
8	1,614,300,710	4
9	1,605,693,706	3
10	1,618,429,444	5
11	1,745,308,471	11

Table 5.19: Total Cost of Each Proposed Alternative

From table 5.19, Case 6: Add 3 Rails at the beginning of the year 2004 generates the lowest total cost. Therefore, it is selected as the optimal solution.

5.10 The LPG Distribution Plan for a Five-Year-Period

From the selected optimal solution, case 6, to make 3 new rails join the system at the beginning of the year 2004, therefore, the LPG distribution plan for five-year-period consisting of the number of rails and trucks required together with the volume allocation as a final output of this thesis can be summarized in table 5.20 and table 5.21 as follows:

Unit: rails,trucks

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	% Growth
2001	**Truck**	49	36	40	50	41	47	63	57	59	51	60	72	**52.08**	-
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4.00**	-
2002	**Truck**	59	57	54	54	52	60	65	65	76	60	65	75	**61.83**	**18.72**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4.00**	-
2003	**Truck**	71	69	66	61	60	71	73	81	73	68	85	75	**71.08**	**14.96**
	Rail	4	4	4	4	4	4	4	4	4	4	4	4	**4.00**	-
2004	**Truck**	32	28	20	23	23	29	24	19	24	25	30	21	**24.83**	**-65.06**
	Rail	7	7	7	7	7	7	7	7	7	7	7	7	**7.00**	**75.00**
2005	**Truck**	29	28	26	26	25	25	28	28	25	26	31	29	**27.17**	**9.40**
	Rail	7	7	7	7	7	7	7	7	7	7	7	7	**7.00**	-

Table 5.20: Number of Rail sand Trucks Required as a Result of the Simulation Model

Unit: tons

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Rail volume from BRP	17,404	16,030	16,030	17,862	17,404	16,946	19,694	19,236	19,236	17,862	18,778	19,694	216,176	18,015
	Total volume from BRP	*17,404*	*16,030*	*16,030*	*17,862*	*17,404*	*16,946*	*19,694*	*19,236*	*19,236*	*17,862*	*18,778*	*19,694*	*216,176*	*18,015*
	Total volume transported	17,404	16,030	16,030	17,862	17,404	16,946	19,694	19,236	19,236	17,862	18,778	19,694	216,176	18,015
	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	4,992	3,520	3,040	3,936	3,488	3,600	5,552	5,984	4,880	4,976	5,792	6,272	56,032	4,669
LMP	Rail volume from BRP	458	458	916	0	458	916	458	458	0	458	458	458	5,496	458
	Total volume from BRP	*5,450*	*3,978*	*3,956*	*3,936*	*3,946*	*4,516*	*6,010*	*6,442*	*4,880*	*5,434*	*6,250*	*6,730*	*61,528*	*5,127*
	Total volume transported	14,874	12,490	13,380	13,056	13,370	13,636	15,434	15,866	14,000	14,858	15,370	16,154	172,488	14,374
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	512	144	0	160	0	48	1,840	2,048	2,192	1,008	2,144	3,248	13,344	1,112
NSW	Rail volume from BRP	10,200	9,690	10,200	10,200	10,200	9,690	9,180	9,180	9,180	9,690	9,180	8,670	115,260	9,605
	Total volume from BRP	*10,712*	*9,834*	*10,200*	*10,360*	*10,200*	*9,738*	*11,020*	*11,228*	*11,372*	*10,698*	*11,324*	*11,918*	*128,604*	*10,717*
	Total volume transported	10,712	9,834	10,200	10,360	10,200	9,738	11,020	11,228	11,372	10,698	11,324	11,918	128,604	10,717
	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	5,504	3,664	3,040	4,096	3,488	3,648	7,392	8,032	7,072	5,984	7,936	9,520	69,376	5,781
Total	Rail volume from BRP	28,062	26,178	27,146	28,062	28,062	27,552	29,332	28,874	28,416	28,010	28,416	28,822	336,932	28,078
	Total volume from BRP	*33,566*	*29,842*	*30,186*	*32,158*	*31,550*	*31,200*	*36,724*	*36,906*	*35,488*	*33,994*	*36,352*	*38,342*	*406,308*	*33,859*
	Total volume transported	42,990	38,354	39,610	41,278	40,974	40,320	46,148	46,330	44,608	43,418	45,472	47,766	517,268	43,106

Table 5.21: LPG Volume Allocation as a Result of the Simulation Model as of 2001-2005

Unit: tons

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Rail volume from BRP	19,236	17,404	18,320	18,320	18,320	18,778	19,236	20,152	20,152	18,320	19,236	21,068	228,542	19,045
	Total volume from BRP	*19,236*	*17,404*	*18,320*	*18,320*	*18,320*	*18,778*	*19,236*	*20,152*	*20,152*	*18,320*	*19,236*	*21,068*	*228,542*	*19,045*
	Total volume transported	19,236	17,404	18,320	18,320	18,320	18,778	19,236	20,152	20,152	18,320	19,236	21,068	228,542	19,045
	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	5,984	5,472	5,600	5,344	5,008	5,456	6,592	7,008	6,576	6,016	7,216	7,696	73,968	6,164
LMP	Rail volume from BRP	458	458	458	458	458	458	458	458	0	458	458	458	5,038	420
	Total volume from BRP	*6,442*	*5,930*	*6,058*	*5,802*	*5,466*	*5,914*	*7,050*	*7,466*	*6,576*	*6,474*	*7,674*	*8,154*	*79,006*	*6,584*
	Total volume transported	15,866	14,442	15,482	14,922	14,890	15,034	16,474	16,890	15,696	15,898	16,794	17,578	189,966	15,831
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	2,624	1,040	560	624	1,024	1,296	3,024	3,504	3,856	2,528	3,440	4,640	28,160	2,347
NSW	Rail volume from BRP	8,670	8,670	10,200	9,690	9,690	9,180	8,160	8,160	8,160	8,670	8,160	7,650	105,060	8,755
	Total volume from BRP	*11,294*	*9,710*	*10,760*	*10,314*	*10,714*	*10,476*	*11,184*	*11,664*	*12,016*	*11,198*	*11,600*	*12,290*	*133,220*	*11,102*
	Total volume transported	11,294	9,710	10,760	10,314	10,714	10,476	11,184	11,664	12,016	11,198	11,600	12,290	133,220	11,102
	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	8,608	6,512	6,160	5,968	6,032	6,752	9,616	10,512	10,432	8,544	10,656	12,336	102,128	8,511
Total	Rail volume from BRP	28,364	26,532	28,978	28,468	28,468	28,416	27,854	28,770	28,312	27,448	27,854	29,176	338,640	28,220
	Total volume from BRP	*36,972*	*33,044*	*35,138*	*34,436*	*34,500*	*35,168*	*37,470*	*39,282*	*38,744*	*35,992*	*38,510*	*41,512*	*440,768*	*36,731*
	Total volume transported	46,396	41,556	44,562	43,556	43,924	44,288	46,894	48,706	47,864	45,416	47,630	50,936	551,728	45,977

Table 5.21: LPG Volume Allocation as a Result of the Simulation Model as of 2001-2005 (Cont.)

Unit: tons

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Rail volume from BRP	19,236	18,778	19,694	19,236	19,236	19,694	21,068	21,984	20,610	20,152	20,610	20,610	240,908	20,076
	Total volume from BRP	*19,236*	*18,778*	*19,694*	*19,236*	*19,236*	*19,694*	*21,068*	*21,984*	*20,610*	*20,152*	*20,610*	*20,610*	*240,908*	*20,076*
	Total volume transported	19,236	18,778	19,694	19,236	19,236	19,694	21,068	21,984	20,610	20,152	20,610	20,610	240,908	20,076
	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	7,552	6,528	6,592	6,256	6,000	6,576	7,568	8,496	7,280	7,008	8,464	8,496	86,816	7,235
LMP	Rail volume from BRP	458	0	0	0	458	458	458	458	458	0	458	458	3,664	305
	Total volume from BRP	*8,010*	*6,528*	*6,592*	*6,256*	*6,458*	*7,034*	*8,026*	*8,954*	*7,738*	*7,008*	*8,922*	*8,954*	*90,480*	*7,540*
	Total volume transported	17,434	15,040	16,016	15,376	15,882	16,154	17,450	18,378	16,858	16,432	18,042	18,378	201,440	16,787
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	4,048	2,624	2,304	2,032	2,576	2,768	4,656	5,664	5,024	4,144	5,136	6,000	46,976	3,915
NSW	Rail volume from BRP	8,160	7,650	9,180	8,670	8,160	8,160	7,140	6,630	7,140	8,160	7,140	6,630	92,820	7,735
	Total volume from BRP	*12,208*	*10,274*	*11,484*	*10,702*	*10,736*	*10,928*	*11,796*	*12,294*	*12,164*	*12,304*	*12,276*	*12,630*	*139,796*	*11,650*
	Total volume transported	12,208	10,274	11,484	10,702	10,736	10,928	11,796	12,294	12,164	12,304	12,276	12,630	139,796	11,650
	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	11,600	9,152	8,896	8,288	8,576	9,344	12,224	14,160	12,304	11,152	13,600	14,496	133,792	11,149
Total	Rail volume from BRP	27,854	26,428	28,874	27,906	27,854	28,312	28,666	29,072	28,208	28,312	28,208	27,698	337,392	28,116
	Total volume from BRP	*39,454*	*35,580*	*37,770*	*36,194*	*36,430*	*37,656*	*40,890*	*43,232*	*40,512*	*39,464*	*41,808*	*42,194*	*471,184*	*39,265*
	Total volume transported	48,878	44,092	47,194	45,314	45,854	46,776	50,314	52,656	49,632	48,888	50,928	51,618	582,144	48,512

Table 5.21: LPG Volume Allocation as a Result of the Simulation Model as of 2001-2005 (Cont.)

Unit: tons

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Rail volume from BRP	21,068	19,236	20,152	20,610	22,442	21,068	22,900	23,816	21,984	21,526	21,984	22,900	259,686	21,641
	Total volume from BRP	*21,068*	*19,236*	*20,152*	*20,610*	*22,442*	*21,068*	*22,900*	*23,816*	*21,984*	*21,526*	*21,984*	*22,900*	*259,686*	*21,641*
	Total volume transported	21,068	19,236	20,152	20,610	22,442	21,068	22,900	23,816	21,984	21,526	21,984	22,900	259,686	21,641
	Truck volume from LKB	9,424	8,816	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	111,264	9,272
	Truck volume from BRP	272	288	32	96	96	80	176	848	432	416	688	832	4,256	355
LMP	Rail volume from BRP	7,786	7,328	6,870	6,412	7,786	7,328	7,786	9,160	7,786	8,244	7,328	8,244	92,058	7,672
	Total volume from BRP	*8,058*	*7,616*	*6,902*	*6,508*	*7,882*	*7,408*	*7,962*	*10,008*	*8,218*	*8,660*	*8,016*	*9,076*	*96,314*	*8,026*
	Total volume transported	17,482	16,432	16,326	15,628	17,306	16,528	17,386	19,432	17,338	18,084	17,136	18,500	207,578	17,298
	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	0	0	0	0	0	0	0	0	16	0	48	0	64	5
NSW	Rail volume from BRP	12,240	11,730	11,730	11,730	11,730	11,220	12,240	13,260	12,240	13,260	12,750	13,260	147,390	12,283
	Total volume from BRP	*12,240*	*11,730*	*11,730*	*11,730*	*11,730*	*11,220*	*12,240*	*13,260*	*12,256*	*13,260*	*12,798*	*13,260*	*147,454*	*12,288*
	Total volume transported	12,240	11,730	11,730	11,730	11,730	11,220	12,240	13,260	12,256	13,260	12,798	13,260	147,454	12,288
	Truck volume from LKB	9,424	8,816	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	111,264	9,272
	Truck volume from BRP	272	288	32	96	96	80	176	848	448	416	736	832	4,320	360
Total	Rail volume from BRP	41,094	38,294	38,752	38,752	41,958	39,616	42,926	46,236	42,010	43,030	42,062	44,404	499,134	41,595
	Total volume from BRP	*41,366*	*38,582*	*38,784*	*38,848*	*42,054*	*39,696*	*43,102*	*47,084*	*42,458*	*43,446*	*42,798*	*45,236*	*503,454*	*41,955*
	Total volume transported	50,790	47,398	48,208	47,968	51,478	48,816	52,526	56,508	51,578	52,870	51,918	54,660	614,718	51,227

Table 5.21: LPG Volume Allocation as a Result of the Simulation Model as of 2001-2005 (Cont.)

Unit: tons

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
KKN	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rail volume from BRP	22,900	20,152	21,984	20,610	22,900	21,984	23,358	23,358	22,900	23,358	22,442	23,816	269,762	22,480
	Total volume from BRP	*22,900*	*20,152*	*21,984*	*20,610*	*22,900*	*21,984*	*23,358*	*23,358*	*22,900*	*23,358*	*22,442*	*23,816*	*269,762*	*22,480*
	Total volume transported	22,900	20,152	21,984	20,610	22,900	21,984	23,358	23,358	22,900	23,358	22,442	23,816	269,762	22,480
LMP	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	752	752	336	320	480	480	1,168	848	880	944	1,136	976	9,072	756
	Rail volume from BRP	8,244	7,786	8,702	7,786	8,702	7,328	8,702	9,160	7,786	8,244	8,244	9,618	100,302	8,359
	Total volume from BRP	*8,996*	*8,538*	*9,038*	*8,106*	*9,182*	*7,808*	*9,870*	*10,008*	*8,666*	*9,188*	*9,380*	*10,594*	*109,374*	*9,115*
	Total volume transported	18,420	17,050	18,462	17,226	18,606	16,928	19,294	19,432	17,786	18,612	18,500	20,018	220,334	18,361
NSW	Truck volume from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck volume from BRP	96	32	16	0	48	0	0	224	80	96	192	368	1,152	96
	Rail volume from BRP	13,770	12,240	12,750	11,220	12,750	11,730	12,750	13,260	13,770	13,770	13,260	13,770	155,040	12,920
	Total volume from BRP	*13,866*	*12,272*	*12,766*	*11,220*	*12,798*	*11,730*	*12,750*	*13,484*	*13,850*	*13,866*	*13,452*	*14,138*	*156,192*	*13,016*
	Total volume transported	13,866	12,272	12,766	11,220	12,798	11,730	12,750	13,484	13,850	13,866	13,452	14,138	156,192	13,016
Total	Truck volume from LKB	9,424	8,512	9,424	9,120	9,424	9,120	9,424	9,424	9,120	9,424	9,120	9,424	110,960	9,247
	Truck volume from BRP	848	784	352	320	528	480	1,168	1,072	960	1,040	1,328	1,344	10,224	852
	Rail volume from BRP	44,914	40,178	43,436	39,616	44,352	41,042	44,810	45,778	44,456	45,372	43,946	47,204	525,104	43,759
	Total volume from BRP	*45,762*	*40,962*	*43,788*	*39,936*	*44,880*	*41,522*	*45,978*	*46,850*	*45,416*	*46,412*	*45,274*	*48,548*	*535,328*	*44,611*
	Total volume transported	55,186	49,474	53,212	49,056	54,304	50,642	55,402	56,274	54,536	55,836	54,394	57,972	646,288	53,857

Table 5.21: LPG Volume Allocation as a Result of the Simulation Model as of 2001-2005 (Cont.)

For other set of the related results: transportation trips, transportation cost, transportation cost per unit volume, inventory status, monthly demand compared with those of plan, resource utilization based on total simulation time, and resource utilization based on total working hours are summarized in appendix L, appendix M, appendix N, appendix O, appendix P, appendix Q, and appendix R respectively.

In addition, in order to make 3 rails join the distribution system at the beginning of the year 2004, a management decision must be launched no later than the beginning of the year 2001 to invest in 3 rails.

5.11 Comparison between the Theoretical Result and the Simulation Result

As discussed in Chapter 4, the difference between the theoretical result and that of the simulation is caused by the uncertainties occur in real world operation. In this part, these two sets of results will be compared to see the affect of these uncertainties.

Since rail is major transportation equipment, in a comparison, the theoretical result, shown in table 4.6, in the case of 7 rails in the year 2004 and 2005 will be compared with the result of the simulation in order to make this comparison base on the same basis. The comparison is illustrated in table 5.22.

#Truck (trucks)	2001 (4 rails)			2002 (4 rails)			2003 (4 rails)			2004 (7 rails)			2005 (7 rails)		
	Theory	Sim.	±%	Theory	Sim.	±%	Theory	Sim.	±%	Theory	Sim.	±%	Theory	Sim.	±%
Jan	30	49	63.33	38	59	55.50	45	71	56.13	19	32	65.29	19	29	49.80
Feb	30	36	21.54	37	57	52.74	45	69	52.64	19	28	44.63	19	28	44.63
Mar	24	40	63.27	32	54	70.70	39	66	70.15	19	20	3.31	19	26	34.30
Apr	27	50	82.95	34	54	57.50	41	61	47.75	19	23	18.81	19	26	34.30
May	25	41	67.07	32	52	64.06	39	60	55.33	19	23	18.81	19	25	29.14
Jun	27	47	72.24	34	60	75.11	42	71	69.31	19	29	49.80	19	25	29.14
Jul	33	63	91.70	40	65	61.69	48	73	53.20	19	24	23.97	20	28	42.16
Aug	36	57	58.39	44	65	48.12	52	81	56.45	19	19	-	24	28	18.62
Sep	35	59	69.83	43	76	77.41	51	73	43.81	19	24	23.97	22	25	12.99
Oct	31	51	65.55	38	60	57.30	46	68	49.31	19	25	29.14	19	26	34.30
Nov	38	60	55.88	47	65	39.52	55	85	55.94	19	30	54.96	26	31	19.70
Dec	39	72	84.76	47	75	60.10	55	75	36.58	19	21	8.47	27	29	9.07
Average	31.26	52.08	66.61	38.80	61.83	59.35	46.37	71.08	53.29	19.33	24.83	28.47	21.12	27.17	28.64

Table 5.22: Comparison between the Theoretical Result and the Simulation Result

From table 5.22, the simulation result is different from the theoretical result by approximately 47%. This difference shows the effect of all the uncertainties occur in the real world. For example, the actual demand in real operation is normally greater than that of the plan as discussed in section 5.4.2.1. The larger number of trucks used in real world is also due to the fluctuation in transportation turnaround time as explained in section 5.4.2.2. Besides those issues, the failure of rail and truck is also one of the major causes that makes the simulation result differs from the theory as explained in section 5.4.2.3. Moreover, as addressed in section 5.4.2.4 and 5.4.2.5, the uncertainties in loading and unloading operation also have an effect on the overall operating system. All these items cannot be absorbed by the theoretical result. That's why a simulation result is more practical than that of the theory. In addition, the difference in the year 2004 and 2005 is smaller than those of the year 2001 through 2003. This characteristic illustrates that the system will be more stable if there are a larger number of rails in the system. In other words, rail transportation makes the system more stable.

5.12 Sensitivity Analysis

In real working environment, customers' demand may deviate from the expected amount depending on an economic growth, the policy of the National Energy Policy Office, etc. Hence, a sensitivity analysis should be applied in order to figure out the range of the deviation in demand that the selected optimal solution can stand for. Moreover, new optimal solution when the demand deviates beyond the optimal point will be identified.

A sensitivity analysis conducted here will be accomplished by varying the demand of each destination depot in order to figure out the changing point of the optimal solution. Result of this analysis is illustrated in table 5.23.

Case	**Total Cost** (baht)				
	-4%	**-3%**	**Plan**	**+5%**	**+6%**
1	1,559,123,283	1,592,354,519	1,694,712,880	1,842,922,437	1,867,265,615
2	1,523,929,354	1,560,667,014	1,660,349,434	1,811,255,553	1,835,611,070
3	1,498,668,121	1,531,592,034	1,628,274,505	1,771,948,336	1,795,275,629
4	1,515,542,980	1,544,613,738	1,637,664,516	1,774,498,746	1,800,672,219
5	***1,490,281,747***	1,515,538,758	1,605,589,588	1,735,191,529	1,760,336,778
6	1,491,923,384	***1,513,122,000***	***1,596,982,583***	***1,713,435,314***	1,735,615,155
7	1,525,941,799	1,555,476,356	1,646,375,639	1,776,660,598	1,800,394,908
8	1,500,680,566	1,526,401,376	1,614,300,710	1,737,353,381	1,760,059,467
9	1,502,322,202	1,523,984,618	1,605,693,706	1,715,597,166	***1,735,337,844***
10	1,516,568,163	1,537,622,033	1,618,429,444	1,725,574,484	1,744,833,374
11	1,591,708,346	1,612,067,607	1,745,308,471	1,846,164,017	1,868,892,888

Table 5.23: Sensitivity Analysis

From table 5.23, within the range of -3% to +5%, the optimal solution will not be changed. Case 6, investing in 3 rails and make it joins the system at the beginning of the year 2004 is the optimal solution. If the demand decreases from the forecasted plan more than 3%, the optimal solution will be changed to buying 2 rails at the beginning of the year 2004 and another one rail at the beginning of the year 2005, case 5. And if the demand is greater than the expected amount more than 5%, buying 3 rails at the beginning of the year 2004 and another one rail at the beginning of the year 2005 will be the optimal solution instead, case 9.

From the sensitivity analysis, it can be said that the optimal solution is quite stable. However, the final solution whether or not to invest in rail depends on the decision of the management.

In the next chapter, all the work done in Chapter 1 through Chapter 5 will be concluded. In addition, comments and suggestions are addresses as well.

CHAPTER 6

CONCLUSION

In order to efficiently implement the LPG distribution plan for a five-year-period proposed in Chapter 5, there are some interesting issues that should be carefully concerned. Here in this chapter, those issues will be focused on. In addition, other related issues such as a problem found while doing this research, comments, etc. will be addressed to end up this chapter.

6.1 Some Interesting Issues

1. In order to make a decision to invest in rail, a further study should be applied by expanding a period of study. A time period of the studying should be extended. The analysis proposed in this thesis is just a primary solution for only five-year-period. A further analysis should be conducted to cover the pay back period of the rails invested. The period of the proposed plan may be extended to from five years to eight or ten years. This further analysis will give a clearer scenario of the plan in the future that will better guide the management to make a more practical decision.

2. When rail is added into the LPG distribution system, no matter how many rails, the number of trucks required in the system will be decreased inevitably because of its higher freight. As explained in Chapter 3, it is a responsibility of the truck contractor to procure trucks to serve PTT's requirement. Therefore, theoretically, PTT pays nothing for the changing in the number of trucks in the transportation fleet. However, this perception may not always be satisfied, especially for the truck contractor. The truck contractors should be informed in advance in order to allow them to be able to find other jobs for their trucks that are going to be idle. However, in doing business, a synergy between business and business is crucial and should be taken care

of. Therefore, the management must give a clear policy of how to do with the trucks in the existing fleet. How many trucks should be kept and how many trucks should be cut down in order to find a satisfied trade-off between PTT and the truck contractors. This agreement must be clearly identified by the management before launching any decision.

3. PTT should inform the State Railway of Thailand about investing in the new rails in advance. The State Railway of Thailand has a responsibility to provide a locomotive engine for PTT's rail according to the PTT requirement. Furthermore, the State Railway of Thailand has to set a transportation schedule for these new rails to allow them to use the railway in order to organize the system of rail transportation in Thailand as a whole to prevent any congestion on the railway that may occur. Otherwise the transportation of the new-LPG-rails may interfere the passenger transportation system, the oil transportation system, the other goods transportation system, etc. Therefore, investing in these new rails should be perceived by the State Railway of Thailand in advance in order to ensure the possibility of having the locomotive engine for the new rails and also the transportation schedule for operating these new facilities.

4. About the character of the market in the future, to be honestly, it is hard to be predicted and identified. The characteristic of the market in the long future is unpredictable because it depends on the policy of the National Energy Policy Office. The National Energy Policy Office has a policy to completely float the price of LPG in the future. It means that the price of LPG will be completely effected by a mechanism of the market, no interfere from the government agency. However, the National Energy Policy Office cannot exactly identify the exact date of launching this policy. Hence, the demand of the far future is still hard to identify. This issue may affect the investment decision of the management because if the price-floating-policy is released

by the National Energy Policy Office, it may affect the LPG volume that PTT has to transported to serve the customer's demand in the regional area. If the volume is decreased, investment in rails may not be worthwhile.

6.2 Suggestions

In order to more efficiently utilize the existing number of rails that PTT has while in the period of procuring new rails, the demand at each destination depot should be balanced. Especially, for LMP and NSW, there should be a study to figure out the possibility in moving some parts of the customers of LMP to NSW. This suggestion can significantly reduce the number of rail sent to LMP and make a rate of rail utilization much higher. As discussed in Chapter 3, rail turnaround time to LMP takes much longer time than that of NSW resulting in a drastically decreasing in the total rail transportation capacity. However, it may be difficult to make this alternative effective because it directly affects the customers who PTT has a policy to do its best to provide them the highest satisfaction though it significantly improves the rail transportation capacity of the existing number of rails in the present fleet.

6.3 Problem Found While Doing the Research and Comment

This research cannot be done without a kind cooperation of many people. In doing this research, there are many parties involved in providing the necessary data, giving a cooperation and also other necessary facilities. The problems found while conducting this research may be concluded as follows:

1. Data collection. Though almost all the necessary data can be found within the organization, there is a notice that these data have not been categorized or organized into a practical format. Some data are gathered by more than

one department which is redundancy and sometimes confuse. On the contrary, some data have been overlooked by everyone. Hence, in order to enhance the entire working efficiency of the organization as a whole, a central database system should be formally set and continuously supported by the management to make it correct and always available for use.

2. Computer software. In doing this research, licensed simulation software is necessary. However, there is a limited quantity of this type of software provided. Consequently, working with the simulation model is sometimes not as convenient as it should be. Hence, if it is possible, more licensed software should be provided.

All the works done in Chapter 1 through Chapter 5 are the attempts to formulate the LPG distribution plan for a five-year-period for the Petroleum Authority of Thailand to achieve the purpose of the study. Besides the plan proposed, other information provided in this thesis may be used as a primary reference in planning other related facilities as well.

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APPENDICES

Appendix A

Transportation Trips as a Result of the LP Model (No rail is added)

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Truck in BRP Fleet (trucks)		10.64	10.26	5.14	7.97	5.18	7.93	13.50	16.63	15.38	11.45	19.13	19.61	11.90
Rail (rails)		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total truck required (trucks)		30.00	29.62	24.50	27.33	24.54	27.29	32.86	35.99	34.74	30.81	38.49	38.97	31.26
KKN (trips)	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Rail from BRP	35.81	32.53	34.28	34.93	35.59	34.93	37.55	38.21	37.34	36.68	37.34	39.30	36.21
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
LMP (trips)	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
	Truck from BRP	164.94	143.64	79.67	119.55	80.30	118.91	209.32	257.73	230.71	177.44	286.96	303.97	181.10
	Rail from BRP	2.31	2.03	3.76	2.83	3.30	2.63	1.63	0.82	0.25	1.88	0.25	0.07	1.81
	Total truck trips	765.08	685.71	679.81	700.33	680.44	699.69	809.46	857.87	811.50	777.58	867.75	904.11	769.94
NSW (trips)	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Rail from BRP	21.57	19.41	20.20	19.41	19.80	19.80	21.18	22.16	22.16	21.57	22.16	22.55	21.00
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
Total (trips)	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
	Truck from BRP	164.94	143.64	79.67	119.55	80.30	118.91	209.32	257.73	230.71	177.44	286.96	303.97	181.10
	Rail from BRP	59.69	53.97	58.24	57.17	58.70	57.37	60.37	61.18	59.75	60.12	59.75	61.93	59.02
	Total truck trips	765.08	685.71	679.81	700.33	680.44	699.69	809.46	857.87	811.50	777.58	867.75	904.11	769.94

Table A-1: Number of Rail and Truck Required as a Result of the LP Model as of 2001-2005 (No rail is added)

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Truck in BRP Fleet (trucks)		18.58	17.96	12.27	14.93	12.34	14.90	20.84	24.53	23.48	18.78	27.23	27.49	19.44
Rail (rails)		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total truck required (trucks)		37.94	37.32	31.63	34.29	31.70	34.26	40.20	43.88	42.84	38.14	46.59	46.84	38.80
	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
KKN	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
(trips)	Rail from BRP	37.99	34.28	36.03	36.68	37.55	36.90	39.52	40.17	39.52	38.65	39.52	41.48	38.19
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
LMP	Truck from BRP	288.02	251.43	190.25	223.89	191.21	223.57	323.04	356.11	306.72	291.15	362.97	374.86	281.93
(trips)	Rail from BRP	0.63	0.66	2.30	1.37	1.83	1.16	0.06	*0.00*	*0.00*	0.30	*0.00*	*0.00*	0.69
	Total truck trips	888.16	793.49	790.39	804.67	791.35	804.35	923.18	956.25	887.50	891.29	943.75	975.00	870.78
	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
NSW	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	48.07	90.94	*0.00*	90.94	102.33	27.69
(trips)	Rail from BRP	22.75	20.39	21.37	20.59	20.78	20.78	22.35	21.83	20.48	22.75	20.48	20.52	21.26
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	48.07	90.94	*0.00*	90.94	102.33	27.69
	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
Total	Truck from BRP	288.02	251.43	190.25	223.89	191.21	223.57	323.04	404.18	397.66	291.15	453.91	477.18	309.62
(trips)	Rail from BRP	61.37	55.34	59.70	58.63	60.17	58.84	61.94	62.00	60.00	61.70	60.00	62.00	60.14
	Total truck trips	888.16	793.49	790.39	804.67	791.35	804.35	923.18	1004.32	978.44	891.29	1034.69	1077.33	898.47

Table A-1: Number of Rail and Truck Required as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Truck in BRP Fleet (trucks)		26.12	25.85	19.43	21.93	19.27	22.57	28.29	32.42	31.40	26.18	35.15	35.55	27.01
Rail (rails)		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total truck required (trucks)		45.47	45.20	38.79	41.29	38.63	41.93	47.65	51.77	50.76	45.54	54.51	54.91	46.37
	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
KKN	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
(trips)	Rail from BRP	39.96	36.24	37.99	38.65	39.52	38.86	41.48	42.36	41.48	40.61	41.48	43.45	40.17
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
LMP	Truck from BRP	374.86	332.94	301.16	325.47	298.67	325.47	393.61	424.86	375.47	368.61	431.72	449.86	366.89
(trips)	Rail from BRP	*0.00*	*0.00*	0.83	*0.00*	0.26	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.09
	Total truck trips	975.00	875.00	901.30	906.25	898.81	906.25	993.75	1,025.00	956.25	968.75	1,012.50	1,050.00	955.74
	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
NSW	Truck from BRP	59.86	57.79	0.00	6.85	0.00	26.31	89.83	155.16	191.08	74.49	191.08	202.46	87.91
(trips)	Rail from BRP	22.04	19.76	22.35	21.35	21.96	21.14	20.52	19.64	18.52	21.39	18.52	18.55	20.48
	Total truck trips	59.86	57.79	*0.00*	6.85	*0.00*	26.31	89.83	155.16	191.08	74.49	191.08	202.46	87.91
	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
Total	Truck from BRP	434.72	390.73	301.16	332.32	298.67	351.78	483.43	580.02	566.54	443.10	622.79	652.32	454.80
(trips)	Rail from BRP	62.00	56.00	61.17	60.00	61.74	60.00	62.00	62.00	60.00	62.00	60.00	62.00	60.74
	Total truck trips	1,034.86	932.79	901.30	913.10	898.81	932.56	1,083.58	1,180.16	1,147.33	1,043.24	1,203.58	1,252.46	1,043.65

Table A-1: Number of Rail and Truck Required as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Truck in BRP Fleet (trucks)		34.18	28.73	26.52	29.64	26.68	29.87	36.18	40.48	38.90	33.45	42.86	43.44	34.25
Rail (rails)		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total truck required (trucks)		53.54	48.09	45.88	49.00	46.04	49.23	55.54	59.84	58.26	52.81	62.22	62.80	53.60
KKN (trips)	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Rail from BRP	41.92	37.99	39.96	40.61	41.48	40.83	43.67	44.32	43.45	42.58	43.45	45.63	42.16
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
LMP (trips)	Truck from GSP LKB	600.14	561.42	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	590.46
	Truck from BRP	449.86	376.08	387.36	394.22	374.86	387.97	462.36	499.86	437.97	431.11	500.47	518.61	435.06
	Rail from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Total truck trips	1,050.00	937.50	987.50	975.00	975.00	968.75	1,062.50	1,100.00	1,018.75	1,031.25	1,081.25	1,118.75	1,025.52
NSW (trips)	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from BRP	159.99	80.97	47.36	100.74	77.33	120.20	196.92	255.30	291.21	174.62	284.96	309.56	174.93
	Rail from BRP	20.08	20.01	22.04	19.39	20.52	19.17	18.33	17.68	16.55	19.42	16.55	16.37	18.84
	Total truck trips	159.99	80.97	47.36	100.74	77.33	120.20	196.92	255.30	291.21	174.62	284.96	309.56	174.93
Total (trips)	Truck from GSP LKB	600.14	561.42	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	590.46
	Truck from BRP	609.85	457.05	434.72	494.96	452.18	508.17	659.28	755.16	729.18	605.73	785.43	828.17	609.99
	Rail from BRP	62.00	58.00	62.00	60.00	62.00	60.00	62.00	62.00	60.00	62.00	60.00	62.00	61.00
	Total truck trips	1,209.99	1,018.47	1,034.86	1,075.74	1,052.33	1,088.95	1,259.42	1,355.30	1,309.96	1,205.87	1,366.21	1,428.31	1,200.45

Table A-1: Number of Rail and Truck Required as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36	19.36
Truck in BRP Fleet (trucks)		42.07	41.45	34.18	37.14	33.94	37.38	44.25	48.37	47.06	41.11	50.78	51.51	42.44
Rail (rails)		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total truck required (trucks)		61.43	60.81	53.54	56.50	53.30	56.74	63.61	67.73	66.42	60.47	70.14	70.87	61.80
	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
KKN	Truck from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
(trips)	Rail from BRP	44.10	39.96	41.92	42.58	43.45	42.79	45.63	46.51	45.63	44.54	45.41	47.60	44.18
	Total truck trips	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
LMP	Truck from BRP	518.61	457.94	456.11	456.72	437.36	450.47	537.36	568.61	506.72	499.86	569.22	593.61	504.38
(trips)	Rail from BRP	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
	Total truck trips	1,118.75	1,000.00	1,056.25	1,037.50	1,037.50	1,031.25	1,137.50	1,168.75	1,087.50	1,100.00	1,150.00	1,193.75	1,093.23
	Truck from GSP LKB	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	0.00
NSW	Truck from BRP	267.09	244.86	147.49	200.87	177.46	220.33	297.06	362.40	398.31	274.76	385.10	409.69	282.12
(trips)	Rail from BRP	17.90	16.04	20.08	17.42	18.55	17.21	16.37	15.49	14.37	17.46	14.59	14.40	16.66
	Total truck trips	267.09	244.86	147.49	200.87	177.46	220.33	297.06	362.40	398.31	274.76	385.10	409.69	282.12
	Truck from GSP LKB	600.14	542.06	600.14	580.78	600.14	580.78	600.14	600.14	580.78	600.14	580.78	600.14	588.85
Total	Truck from BRP	785.70	702.80	603.60	657.59	614.82	670.80	834.42	931.01	905.03	774.62	954.32	1,003.30	786.50
(trips)	Rail from BRP	62.00	56.00	62.00	60.00	62.00	60.00	62.00	62.00	60.00	62.00	60.00	62.00	60.83
	Total truck trips	1,385.84	1,244.86	1,203.74	1,238.37	1,214.96	1,251.58	1,434.56	1,531.15	1,485.81	1,374.76	1,535.10	1,603.44	1,375.35

Table A-1: Number of Rail and Truck Required as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Appendix B

Volume Allocation as a Result of the LP Model (No rail is added)

Unit: tons

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
KKN	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Rail volume from BRP	16,400.00	14,900.00	15,700.00	16,000.00	16,300.00	16,000.00	17,200.00	17,500.00	17,100.00	16,800.00	17,100.00	18,000.00	16,583.33
	Total volume from BRP	*16,400.00*	*14,900.00*	*15,700.00*	*16,000.00*	*16,300.00*	*16,000.00*	*17,200.00*	*17,500.00*	*17,100.00*	*16,800.00*	*17,100.00*	*18,000.00*	*16,583.33*
	Total volume transported	**16,400.00**	**14,900.00**	**15,700.00**	**16,000.00**	**16,300.00**	**16,000.00**	**17,200.00**	**17,500.00**	**17,100.00**	**16,800.00**	**17,100.00**	**18,000.00**	**16,583.33**
LMP	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	2,638.97	2,298.29	1,274.65	1,912.79	1,284.85	1,902.60	3,349.16	4,123.67	3,691.42	2,838.97	4,591.42	4,863.48	2,897.52
	Rail volume from BRP	1,058.78	928.71	1,723.10	1,294.71	1,512.90	1,204.90	748.59	374.08	116.08	858.78	116.08	34.27	830.92
	Total volume from BRP	*3,697.75*	*3,227.00*	*2,997.75*	*3,207.50*	*2,797.75*	*3,107.50*	*4,097.75*	*4,497.75*	*3,807.50*	*3,697.75*	*4,707.50*	*4,897.75*	*3,728.44*
	Total volume transported	**13,300.00**	**11,900.00**	**12,600.00**	**12,500.00**	**12,400.00**	**12,400.00**	**13,700.00**	**14,100.00**	**13,100.00**	**13,300.00**	**14,000.00**	**14,500.00**	**13,150.00**
NSW	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Rail volume from BRP	11,000.00	9,900.00	10,300.00	9,900.00	10,100.00	10,100.00	10,800.00	11,300.00	11,300.00	11,000.00	11,300.00	11,500.00	10,708.33
	Total volume from BRP	*11,000.00*	*9,900.00*	*10,300.00*	*9,900.00*	*10,100.00*	*10,100.00*	*10,800.00*	*11,300.00*	*11,300.00*	*11,000.00*	*11,300.00*	*11,500.00*	*10,708.33*
	Total volume transported	**11,000.00**	**9,900.00**	**10,300.00**	**9,900.00**	**10,100.00**	**10,100.00**	**10,800.00**	**11,300.00**	**11,300.00**	**11,000.00**	**11,300.00**	**11,500.00**	**10,708.33**
Total	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	2,638.97	2,298.29	1,274.65	1,912.79	1,284.85	1,902.60	3,349.16	4,123.67	3,691.42	2,838.97	4,591.42	4,863.48	2,897.52
	Rail volume from BRP	28,458.78	25,728.71	27,723.10	27,194.71	27,912.90	27,304.90	28,748.59	29,174.08	28,516.08	28,658.78	28,516.08	29,534.27	28,122.58
	Total volume from BRP	*31,097.75*	*28,027.00*	*28,997.75*	*29,107.50*	*29,197.75*	*29,207.50*	*32,097.75*	*33,297.75*	*32,207.50*	*31,497.75*	*33,107.50*	*34,397.75*	*31,020.10*
	Total volume transported	**40,700.00**	**36,700.00**	**38,600.00**	**38,400.00**	**38,800.00**	**38,500.00**	**41,700.00**	**42,900.00**	**41,500.00**	**41,100.00**	**42,400.00**	**44,000.00**	**40,441.67**

Table B-1: LPG Volume Allocation as a Result of the LP Model as of 2001-2005 (No rail is added)

Unit: tons

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KKN	Rail volume from BRP	17,400.00	15,700.00	16,500.00	16,800.00	17,200.00	16,900.00	18,100.00	18,400.00	18,100.00	17,700.00	18,100.00	19,000.00	17,491.67
	Total volume from BRP	*17,400.00*	*15,700.00*	*16,500.00*	*16,800.00*	*17,200.00*	*16,900.00*	*18,100.00*	*18,400.00*	*18,100.00*	*17,700.00*	*18,100.00*	*19,000.00*	*17,491.67*
	Total volume transported	**17,400.00**	**15,700.00**	**16,500.00**	**16,800.00**	**17,200.00**	**16,900.00**	**18,100.00**	**18,400.00**	**18,100.00**	**17,700.00**	**18,100.00**	**19,000.00**	**17,491.67**
	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	4,608.38	4,022.80	3,044.06	3,582.21	3,059.36	3,577.11	5,168.57	5,697.75	4,907.50	4,658.38	5,807.50	5,997.75	4,510.95
LMP	Rail volume from BRP	289.37	304.20	1,053.69	625.29	838.39	530.39	29.18	0.00	0.00	139.37	0.00	0.00	317.49
	Total volume from BRP	*4,897.75*	*4,327.00*	*4,097.75*	*4,207.50*	*3,897.75*	*4,107.50*	*5,197.75*	*5,697.75*	*4,907.50*	*4,797.75*	*5,807.50*	*5,997.75*	*4,828.44*
	Total volume transported	**14,500.00**	**13,000.00**	**13,700.00**	**13,500.00**	**13,500.00**	**13,400.00**	**14,800.00**	**15,300.00**	**14,200.00**	**14,400.00**	**15,100.00**	**15,600.00**	**14,250.00**
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	769.08	1,455.02	0.00	1,455.02	1,637.21	443.03
NSW	Rail volume from BRP	11,600.00	10,400.00	10,900.00	10,500.00	10,600.00	10,600.00	11,400.00	11,130.92	10,444.98	11,600.00	10,444.98	10,462.79	10,840.31
	Total volume from BRP	*11,600.00*	*10,400.00*	*10,900.00*	*10,500.00*	*10,600.00*	*10,600.00*	*11,400.00*	*11,900.00*	*11,900.00*	*11,600.00*	*11,900.00*	*12,100.00*	*11,283.33*
	Total volume transported	**11,600.00**	**10,400.00**	**10,900.00**	**10,500.00**	**10,600.00**	**10,600.00**	**11,400.00**	**11,900.00**	**11,900.00**	**11,600.00**	**11,900.00**	**12,100.00**	**11,283.33**
	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	4,608.38	4,022.80	3,044.06	3,582.21	3,059.36	3,577.11	5,168.57	6,466.83	6,362.52	4,658.38	7,262.52	7,634.96	4,953.97
Total	Rail volume from BRP	29,289.37	26,404.20	28,453.69	27,925.29	28,638.39	28,030.39	29,529.18	29,530.92	28,544.98	29,439.37	28,544.98	29,462.79	28,649.46
	Total volume from BRP	*33,897.75*	*30,427.00*	*31,497.75*	*31,507.50*	*31,697.75*	*31,607.50*	*34,697.75*	*35,997.75*	*34,907.50*	*34,097.75*	*35,807.50*	*37,097.75*	*33,603.44*
	Total volume transported	**43,500.00**	**39,100.00**	**41,100.00**	**40,800.00**	**41,300.00**	**40,900.00**	**44,300.00**	**45,600.00**	**44,200.00**	**43,700.00**	**45,100.00**	**46,700.00**	**43,025.00**

Table B-1: LPG Volume Allocation as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Unit: tons

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KKN	Rail volume from BRP	18,300.00	16,600.00	17,400.00	17,700.00	18,100.00	17,800.00	19,000.00	19,400.00	19,000.00	18,600.00	19,000.00	19,900.00	18,400.00
	Total volume from BRP	*18,300.00*	*16,600.00*	*17,400.00*	*17,700.00*	*18,100.00*	*17,800.00*	*19,000.00*	*19,400.00*	*19,000.00*	*18,600.00*	*19,000.00*	*19,900.00*	*18,400.00*
	Total volume transported	**18,300.00**	**16,600.00**	**17,400.00**	**17,700.00**	**18,100.00**	**17,800.00**	**19,000.00**	**19,400.00**	**19,000.00**	**18,600.00**	**19,000.00**	**19,900.00**	**18,400.00**
	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	5,997.75	5,327.00	4,818.57	5,207.50	4,778.77	5,207.50	6,297.75	6,797.75	6,007.50	5,897.75	6,907.50	7,197.75	5,870.26
LMP	Rail volume from BRP	0.00	0.00	379.18	0.00	118.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.51
	Total volume from BRP	*5,997.75*	*5,327.00*	*5,197.75*	*5,207.50*	*4,897.75*	*5,207.50*	*6,297.75*	*6,797.75*	*6,007.50*	*5,897.75*	*6,907.50*	*7,197.75*	*5,911.77*
	Total volume transported	**15,600.00**	**14,000.00**	**14,800.00**	**14,500.00**	**14,500.00**	**14,500.00**	**15,900.00**	**16,400.00**	**15,300.00**	**15,500.00**	**16,200.00**	**16,800.00**	**15,333.33**
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	957.73	924.72	0.00	109.61	0.00	420.96	1,437.21	2,482.62	3,057.21	1,191.79	3,057.21	3,239.39	1,406.54
NSW	Rail volume from BRP	11,242.27	10,075.28	11,400.00	10,890.39	11,200.00	10,779.04	10,462.79	10,017.38	9,442.79	10,908.21	9,442.79	9,460.61	10,443.46
	Total volume from BRP	*12,200.00*	*11,000.00*	*11,400.00*	*11,000.00*	*11,200.00*	*11,200.00*	*11,900.00*	*12,500.00*	*12,500.00*	*12,100.00*	*12,500.00*	*12,700.00*	*11,850.00*
	Total volume transported	**12,200.00**	**11,000.00**	**11,400.00**	**11,000.00**	**11,200.00**	**11,200.00**	**11,900.00**	**12,500.00**	**12,500.00**	**12,100.00**	**12,500.00**	**12,700.00**	**11,850.00**
	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	6,955.48	6,251.72	4,818.57	5,317.11	4,778.77	5,628.46	7,734.96	9,280.37	9,064.71	7,089.54	9,964.71	10,437.14	7,276.79
Total	Rail volume from BRP	29,542.27	26,675.28	29,179.18	28,590.39	29,418.98	28,579.04	29,462.79	29,417.38	28,442.79	29,508.21	28,442.79	29,360.61	28,884.98
	Total volume from BRP	*36,497.75*	*32,927.00*	*33,997.75*	*33,907.50*	*34,197.75*	*34,207.50*	*37,197.75*	*38,697.75*	*37,507.50*	*36,597.75*	*38,407.50*	*39,797.75*	*36,161.77*
	Total volume transported	**46,100.00**	**41,600.00**	**43,600.00**	**43,200.00**	**43,800.00**	**43,500.00**	**46,800.00**	**48,300.00**	**46,800.00**	**46,200.00**	**47,700.00**	**49,400.00**	**45,583.33**

Table B-1: LPG Volume Allocation as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Unit: tons

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KKN	Rail volume from BRP	19,200.00	17,400.00	18,300.00	18,600.00	19,000.00	18,700.00	20,000.00	20,300.00	19,900.00	19,500.00	19,900.00	20,900.00	19,308.33
	Total volume from BRP	*19,200.00*	*17,400.00*	*18,300.00*	*18,600.00*	*19,000.00*	*18,700.00*	*20,000.00*	*20,300.00*	*19,900.00*	*19,500.00*	*19,900.00*	*20,900.00*	*19,308.33*
	Total volume transported	**19,200.00**	**17,400.00**	**18,300.00**	**18,600.00**	**19,000.00**	**18,700.00**	**20,000.00**	**20,300.00**	**19,900.00**	**19,500.00**	**19,900.00**	**20,900.00**	**19,308.33**
	Truck volume from LKB	9,602.25	8,982.75	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,447.38
	Truck volume from BRP	7,197.75	6,017.25	6,197.75	6,307.50	5,997.75	6,207.50	7,397.75	7,997.75	7,007.50	6,897.75	8,007.50	8,297.75	6,960.96
LMP	Rail volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total volume from BRP	*7,197.75*	*6,017.25*	*6,197.75*	*6,307.50*	*5,997.75*	*6,207.50*	*7,397.75*	*7,997.75*	*7,007.50*	*6,897.75*	*8,007.50*	*8,297.75*	*6,960.96*
	Total volume transported	**16,800.00**	**15,000.00**	**15,800.00**	**15,600.00**	**15,600.00**	**15,500.00**	**17,000.00**	**17,600.00**	**16,300.00**	**16,500.00**	**17,300.00**	**17,900.00**	**16,408.33**
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	2,559.91	1,295.55	757.73	1,611.79	1,237.21	1,923.14	3,150.74	4,084.80	4,659.39	2,793.97	4,559.39	4,952.93	2,798.88
NSW	Rail volume from BRP	10,240.09	10,204.45	11,242.27	9,888.21	10,462.79	9,776.86	9,349.26	9,015.20	8,440.61	9,906.03	8,440.61	8,347.07	9,609.45
	Total volume from BRP	*12,800.00*	*11,500.00*	*12,000.00*	*11,500.00*	*11,700.00*	*11,700.00*	*12,500.00*	*13,100.00*	*13,100.00*	*12,700.00*	*13,000.00*	*13,300.00*	*12,408.33*
	Total volume transported	**12,800.00**	**11,500.00**	**12,000.00**	**11,500.00**	**11,700.00**	**11,700.00**	**12,500.00**	**13,100.00**	**13,100.00**	**12,700.00**	**13,000.00**	**13,300.00**	**12,408.33**
	Truck volume from LKB	9,602.25	8,982.75	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,447.38
	Truck volume from BRP	9,757.66	7,312.80	6,955.48	7,919.29	7,234.96	8,130.64	10,548.49	12,082.55	11,666.89	9,691.72	12,566.89	13,250.68	9,759.84
Total	Rail volume from BRP	29,440.09	27,604.45	29,542.27	28,488.21	29,462.79	28,476.86	29,349.26	29,315.20	28,340.61	29,406.03	28,340.61	29,247.07	28,917.79
	Total volume from BRP	*39,197.75*	*34,917.25*	*36,497.75*	*36,407.50*	*36,697.75*	*36,607.50*	*39,897.75*	*41,397.75*	*40,007.50*	*39,097.75*	*40,907.50*	*42,497.75*	*38,677.63*
	Total volume transported	**48,800.00**	**43,900.00**	**46,100.00**	**45,700.00**	**46,300.00**	**45,900.00**	**49,500.00**	**51,000.00**	**49,300.00**	**48,700.00**	**50,200.00**	**52,100.00**	**48,125.00**

Table B-1: LPG Volume Allocation as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Unit: tons

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KKN	Rail volume from BRP	20,200.00	18,300.00	19,200.00	19,500.00	19,900.00	19,600.00	20,900.00	21,300.00	20,900.00	20,400.00	20,800.00	21,800.00	20,233.33
	Total volume from BRP	*20,200.00*	*18,300.00*	*19,200.00*	*19,500.00*	*19,900.00*	*19,600.00*	*20,900.00*	*21,300.00*	*20,900.00*	*20,400.00*	*20,800.00*	*21,800.00*	*20,233.33*
	Total volume transported	**20,200.00**	**18,300.00**	**19,200.00**	**19,500.00**	**19,900.00**	**19,600.00**	**20,900.00**	**21,300.00**	**20,900.00**	**20,400.00**	**20,800.00**	**21,800.00**	**20,233.33**
	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	8,297.75	7,327.00	7,297.75	7,307.50	6,997.75	7,207.50	8,597.75	9,097.75	8,107.50	7,997.75	9,107.50	9,497.75	8,070.10
LMP	Rail volume from BRP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total volume from BRP	*8,297.75*	*7,327.00*	*7,297.75*	*7,307.50*	*6,997.75*	*7,207.50*	*8,597.75*	*9,097.75*	*8,107.50*	*7,997.75*	*9,107.50*	*9,497.75*	*8,070.10*
	Total volume transported	**17,900.00**	**16,000.00**	**16,900.00**	**16,600.00**	**16,600.00**	**16,500.00**	**18,200.00**	**18,700.00**	**17,400.00**	**17,600.00**	**18,400.00**	**19,100.00**	**17,491.67**
	Truck volume from LKB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Truck volume from BRP	4,273.45	3,917.73	2,359.91	3,213.97	2,839.39	3,525.33	4,752.93	5,798.34	6,372.93	4,396.16	6,161.57	6,555.11	4,513.90
NSW	Rail volume from BRP	9,126.55	8,182.27	10,240.09	8,886.03	9,460.61	8,774.67	8,347.07	7,901.66	7,327.07	8,903.84	7,438.43	7,344.89	8,494.43
	Total volume from BRP	*13,400.00*	*12,100.00*	*12,600.00*	*12,100.00*	*12,300.00*	*12,300.00*	*13,100.00*	*13,700.00*	*13,700.00*	*13,300.00*	*13,600.00*	*13,900.00*	*13,008.33*
	Total volume transported	**13,400.00**	**12,100.00**	**12,600.00**	**12,100.00**	**12,300.00**	**12,300.00**	**13,100.00**	**13,700.00**	**13,700.00**	**13,300.00**	**13,600.00**	**13,900.00**	**13,008.33**
	Truck volume from LKB	9,602.25	8,673.00	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,602.25	9,292.50	9,602.25	9,292.50	9,602.25	9,421.56
	Truck volume from BRP	12,571.20	11,244.73	9,657.66	10,521.47	9,837.14	10,732.83	13,350.68	14,896.09	14,480.43	12,393.91	15,269.07	16,052.86	12,584.01
Total	Rail volume from BRP	29,326.55	26,482.27	29,440.09	28,386.03	29,360.61	28,374.67	29,247.07	29,201.66	28,227.07	29,303.84	28,238.43	29,144.89	28,727.77
	Total volume from BRP	*41,897.75*	*37,727.00*	*39,097.75*	*38,907.50*	*39,197.75*	*39,107.50*	*42,597.75*	*44,097.75*	*42,707.50*	*41,697.75*	*43,507.50*	*45,197.75*	*41,311.77*
	Total volume transported	**51,500.00**	**46,400.00**	**48,700.00**	**48,200.00**	**48,800.00**	**48,400.00**	**52,200.00**	**53,700.00**	**52,000.00**	**51,300.00**	**52,800.00**	**54,800.00**	**50,733.33**

Table B-1: LPG Volume Allocation as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Appendix C

Transportation Cost as a Result of the LP Model (No rail is added)

Unit: baht

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	8,298,400	7,539,400	7,944,200	8,096,000	8,247,800	8,096,000	8,703,200	8,855,000	8,652,600	8,500,800	8,652,600	9,108,000	8,391,167
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**8,298,400**	**7,539,400**	**7,944,200**	**8,096,000**	**8,247,800**	**8,096,000**	**8,703,200**	**8,855,000**	**8,652,600**	**8,500,800**	**8,652,600**	**9,108,000**	**8,391,167**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	5,254,181	4,575,904	2,537,832	3,808,373	2,558,132	3,788,073	6,668,181	8,210,230	7,349,620	5,652,381	9,141,520	9,683,180	5,768,967
LMP	Total rail transportation cost	743,267	651,952	1,209,615	908,884	1,062,057	845,841	525,509	262,603	81,487	602,867	81,487	24,061	583,302
	Total truck transportation cost	*13,615,628*	*12,128,179*	*10,899,279*	*11,900,096*	*10,919,580*	*11,879,796*	*15,029,628*	*16,571,677*	*15,441,343*	*14,013,828*	*17,233,244*	*18,044,627*	*13,973,075*
	Total transportation cost	**14,358,895**	**12,780,130**	**12,108,894**	**12,808,980**	**11,981,637**	**12,725,637**	**15,555,137**	**16,834,280**	**15,522,831**	**14,616,695**	**17,314,731**	**18,068,688**	**14,556,378**
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
NSW	Total rail transportation cost	4,202,000	3,781,800	3,934,600	3,781,800	3,858,200	3,858,200	4,125,600	4,316,600	4,316,600	4,202,000	4,316,600	4,393,000	4,090,583
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**4,202,000**	**3,781,800**	**3,934,600**	**3,781,800**	**3,858,200**	**3,858,200**	**4,125,600**	**4,316,600**	**4,316,600**	**4,202,000**	**4,316,600**	**4,393,000**	**4,090,583**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	5,254,181	4,575,904	2,537,832	3,808,373	2,558,132	3,788,073	6,668,181	8,210,230	7,349,620	5,652,381	9,141,520	9,683,180	5,768,967
Total	Total rail transportation cost	13,243,667	11,973,152	13,088,415	12,786,684	13,168,057	12,800,041	13,354,309	13,434,203	13,050,687	13,305,667	13,050,687	13,525,061	13,065,052
	Total truck transportation cost	*13,615,628*	*12,128,179*	*10,899,279*	*11,900,096*	*10,919,580*	*11,879,796*	*15,029,628*	*16,571,677*	*15,441,343*	*14,013,828*	*17,233,244*	*18,044,627*	*13,973,075*
	Total transportation cost	**26,859,295**	**24,101,330**	**23,987,694**	**24,686,780**	**24,087,637**	**24,679,837**	**28,383,937**	**30,005,880**	**28,492,031**	**27,319,495**	**30,283,931**	**31,569,688**	**27,038,128**

Table C-1: Transportation Cost as a Result of the LP Model as of 2001-2005 (No rail is added)

Unit: baht

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	8,804,400	7,944,200	8,349,000	8,500,800	8,703,200	8,551,400	9,158,600	9,310,400	9,158,600	8,956,200	9,158,600	9,614,000	8,850,783
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**8,804,400**	**7,944,200**	**8,349,000**	**8,500,800**	**8,703,200**	**8,551,400**	**9,158,600**	**9,310,400**	**9,158,600**	**8,956,200**	**9,158,600**	**9,614,000**	**8,850,783**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	9,175,279	8,009,403	6,060,731	7,132,172	6,091,181	7,122,022	10,290,630	11,344,220	9,770,833	9,274,830	11,562,733	11,941,520	8,981,296
LMP	Total rail transportation cost	203,140	213,546	739,688	438,956	588,551	372,335	20,482	0	0	97,840	0	0	222,878
	Total truck transportation cost	*17,536,726*	*15,561,678*	*14,422,178*	*15,223,895*	*14,452,629*	*15,213,745*	*18,652,077*	*19,705,668*	*17,862,556*	*17,636,277*	*19,654,456*	*20,302,968*	*17,185,404*
	Total transportation cost	**17,739,866**	**15,775,223**	**15,161,866**	**15,662,852**	**15,041,180**	**15,586,080**	**18,672,559**	**19,705,668**	**17,862,556**	**17,734,116**	**19,654,456**	**20,302,968**	**17,408,282**
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	799,846	1,513,223	0	1,513,223	1,702,693	460,749
NSW	Total rail transportation cost	4,431,200	3,972,800	4,163,800	4,011,000	4,049,200	4,049,200	4,354,800	4,252,010	3,989,982	4,431,200	3,989,982	3,996,788	4,140,997
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*799,846*	*1,513,223*	*0*	*1,513,223*	*1,702,693*	*460,749*
	Total transportation cost	**4,431,200**	**3,972,800**	**4,163,800**	**4,011,000**	**4,049,200**	**4,049,200**	**4,354,800**	**5,051,857**	**5,503,204**	**4,431,200**	**5,503,204**	**5,699,481**	**4,601,746**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	9,175,279	8,009,403	6,060,731	7,132,172	6,091,181	7,122,022	10,290,630	12,144,067	11,284,055	9,274,830	13,075,955	13,644,214	9,442,045
Total	Total rail transportation cost	13,438,740	12,130,546	13,252,488	12,950,756	13,340,951	12,972,935	13,533,882	13,562,410	13,148,582	13,485,240	13,148,582	13,610,788	13,214,658
	Total truck transportation cost	*17,536,726*	*15,561,678*	*14,422,178*	*15,223,895*	*14,452,629*	*15,213,745*	*18,652,077*	*20,505,514*	*19,375,778*	*17,636,277*	*21,167,678*	*22,005,661*	*17,646,153*
	Total transportation cost	**30,975,466**	**27,692,223**	**27,674,666**	**28,174,652**	**27,793,580**	**28,186,680**	**32,185,959**	**34,067,924**	**32,524,360**	**31,121,516**	**34,316,260**	**35,616,449**	**30,860,811**

Table C-1: Transportation Cost as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Unit: baht

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	9,259,800	8,399,600	8,804,400	8,956,200	9,158,600	9,006,800	9,614,000	9,816,400	9,614,000	9,411,600	9,614,000	10,069,400	9,310,400
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**9,259,800**	**8,399,600**	**8,804,400**	**8,956,200**	**9,158,600**	**9,006,800**	**9,614,000**	**9,816,400**	**9,614,000**	**9,411,600**	**9,614,000**	**10,069,400**	**9,310,400**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	11,941,520	10,606,057	9,593,780	10,368,133	9,514,530	10,368,133	12,538,820	13,534,320	11,960,933	11,742,420	13,752,833	14,330,720	11,687,683
LMP	Total rail transportation cost	0	0	266,182	0	83,524	0	0	0	0	0	0	0	29,142
	Total truck transportation cost	*20,302,968*	*18,158,332*	*17,955,227*	*18,459,856*	*17,875,978*	*18,459,856*	*20,900,268*	*21,895,768*	*20,052,656*	*20,103,868*	*21,844,556*	*22,692,168*	*19,891,791*
	Total transportation cost	**20,302,968**	**18,158,332**	**18,221,409**	**18,459,856**	**17,959,502**	**18,459,856**	**20,900,268**	**21,895,768**	**20,052,656**	**20,103,868**	**21,844,556**	**22,692,168**	**19,920,934**
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	996,038	961,705	0	113,991	0	437,799	1,494,693	2,581,925	3,179,493	1,239,462	3,179,493	3,368,964	1,462,797
NSW	Total rail transportation cost	4,294,547	3,848,758	4,354,800	4,160,130	4,278,400	4,117,593	3,996,788	3,826,639	3,607,148	4,166,936	3,607,148	3,613,954	3,989,403
	Total truck transportation cost	*996,038*	*961,705*	*0*	*113,991*	*0*	*437,799*	*1,494,693*	*2,581,925*	*3,179,493*	*1,239,462*	*3,179,493*	*3,368,964*	*1,462,797*
	Total transportation cost	**5,290,586**	**4,810,463**	**4,354,800**	**4,274,121**	**4,278,400**	**4,555,392**	**5,491,481**	**6,408,564**	**6,786,641**	**5,406,398**	**6,786,641**	**6,982,918**	**5,452,200**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	12,937,559	11,567,762	9,593,780	10,482,124	9,514,530	10,805,932	14,033,514	16,116,245	15,140,426	12,981,882	16,932,326	17,699,685	13,150,480
Total	Total rail transportation cost	13,554,347	12,248,358	13,425,382	13,116,330	13,520,524	13,124,393	13,610,788	13,643,039	13,221,148	13,578,536	13,221,148	13,683,354	13,328,946
	Total truck transportation cost	*21,299,006*	*19,120,037*	*17,955,227*	*18,573,847*	*17,875,978*	*18,897,655*	*22,394,961*	*24,477,692*	*23,232,149*	*21,343,329*	*25,024,049*	*26,061,132*	*21,354,588*
	Total transportation cost	**34,853,353**	**31,368,395**	**31,380,609**	**31,690,177**	**31,396,502**	**32,022,048**	**36,005,749**	**38,120,731**	**36,453,297**	**34,921,866**	**38,245,197**	**39,744,485**	**34,683,534**

Table C-1: Transportation Cost as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Unit: baht

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	9,715,200	8,804,400	9,259,800	9,411,600	9,614,000	9,462,200	10,120,000	10,271,800	10,069,400	9,867,000	10,069,400	10,575,400	9,770,017
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**9,715,200**	**8,804,400**	**9,259,800**	**9,411,600**	**9,614,000**	**9,462,200**	**10,120,000**	**10,271,800**	**10,069,400**	**9,867,000**	**10,069,400**	**10,575,400**	**9,770,017**
	Truck transportation cost from LKB	8,361,447	7,821,999	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,226,585
	Truck transportation cost from BRP	14,330,720	11,980,345	12,339,720	12,558,233	11,941,520	12,359,133	14,728,920	15,923,520	13,951,933	13,733,420	15,942,933	16,520,820	13,859,268
LMP	Total rail transportation cost	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total truck transportation cost	*22,692,168*	*19,802,344*	*20,701,168*	*20,649,956*	*20,302,968*	*20,450,856*	*23,090,368*	*24,284,968*	*22,043,656*	*22,094,868*	*24,034,656*	*24,882,268*	*22,085,853*
	Total transportation cost	**22,692,168**	**19,802,344**	**20,701,168**	**20,649,956**	**20,302,968**	**20,450,856**	**23,090,368**	**24,284,968**	**22,043,656**	**22,094,868**	**24,034,656**	**24,882,268**	**22,085,853**
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	2,662,309	1,347,368	788,038	1,676,262	1,286,693	2,000,070	3,276,772	4,248,196	4,845,764	2,905,733	4,741,764	5,151,043	2,910,834
NSW	Total rail transportation cost	3,911,713	3,898,101	4,294,547	3,777,296	3,996,788	3,734,759	3,571,416	3,443,805	3,224,314	3,784,102	3,224,314	3,188,582	3,670,811
	Total truck transportation cost	*2,662,309*	*1,347,368*	*788,038*	*1,676,262*	*1,286,693*	*2,000,070*	*3,276,772*	*4,248,196*	*4,845,764*	*2,905,733*	*4,741,764*	*5,151,043*	*2,910,834*
	Total transportation cost	**6,574,023**	**5,245,469**	**5,082,586**	**5,453,558**	**5,283,481**	**5,734,829**	**6,848,189**	**7,692,001**	**8,070,078**	**6,689,835**	**7,966,078**	**8,339,625**	**6,581,646**
	Truck transportation cost from LKB	8,361,447	7,821,999	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,226,585
	Truck transportation cost from BRP	16,993,029	13,327,712	13,127,759	14,234,495	13,228,214	14,359,202	18,005,692	20,171,716	18,797,697	16,639,153	20,684,697	21,671,863	16,770,102
Total	Total rail transportation cost	13,626,913	12,702,501	13,554,347	13,188,896	13,610,788	13,196,959	13,691,416	13,715,605	13,293,714	13,651,102	13,293,714	13,763,982	13,440,828
	Total truck transportation cost	*25,354,477*	*21,149,712*	*21,489,206*	*22,326,218*	*21,589,661*	*22,450,925*	*26,367,140*	*28,533,163*	*26,889,420*	*25,000,600*	*28,776,420*	*30,033,310*	*24,996,688*
	Total transportation cost	**38,981,390**	**33,852,213**	**35,043,553**	**35,515,114**	**35,200,449**	**35,647,884**	**40,058,556**	**42,248,768**	**40,183,133**	**38,651,702**	**42,070,133**	**43,797,293**	**38,437,516**

Table C-1: Transportation Cost as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Unit: baht

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	10,221,200	9,259,800	9,715,200	9,867,000	10,069,400	9,917,600	10,575,400	10,777,800	10,575,400	10,322,400	10,524,800	11,030,800	10,238,067
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**10,221,200**	**9,259,800**	**9,715,200**	**9,867,000**	**10,069,400**	**9,917,600**	**10,575,400**	**10,777,800**	**10,575,400**	**10,322,400**	**10,524,800**	**11,030,800**	**10,238,067**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	16,520,820	14,588,057	14,529,820	14,549,233	13,932,520	14,350,133	17,118,120	18,113,620	16,142,033	15,923,520	18,133,033	18,910,020	16,067,577
LMP	Total rail transportation cost	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total truck transportation cost	*24,882,268*	*22,140,332*	*22,891,268*	*22,640,956*	*22,293,968*	*22,441,856*	*25,479,568*	*26,475,068*	*24,233,756*	*24,284,968*	*26,224,756*	*27,271,468*	*24,271,686*
	Total transportation cost	**24,882,268**	**22,140,332**	**22,891,268**	**22,640,956**	**22,293,968**	**22,441,856**	**25,479,568**	**26,475,068**	**24,233,756**	**24,284,968**	**26,224,756**	**27,271,468**	**24,271,686**
	Truck transportation cost from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	4,444,388	4,074,438	2,454,309	3,342,533	2,952,964	3,666,341	4,943,043	6,030,274	6,627,843	4,572,003	6,408,035	6,817,313	4,694,457
NSW	Total rail transportation cost	3,486,342	3,125,627	3,911,713	3,394,462	3,613,954	3,351,925	3,188,582	3,018,434	2,798,942	3,401,268	2,841,479	2,805,748	3,244,873
	Total truck transportation cost	*4,444,388*	*4,074,438*	*2,454,309*	*3,342,533*	*2,952,964*	*3,666,341*	*4,943,043*	*6,030,274*	*6,627,843*	*4,572,003*	*6,408,035*	*6,817,313*	*4,694,457*
	Total transportation cost	**7,930,730**	**7,200,066**	**6,366,023**	**6,736,995**	**6,566,918**	**7,018,265**	**8,131,625**	**9,048,708**	**9,426,785**	**7,973,271**	**9,249,514**	**9,623,062**	**7,939,330**
	Truck transportation cost from LKB	8,361,447	7,552,275	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,361,447	8,091,723	8,361,447	8,091,723	8,361,447	8,204,108
	Truck transportation cost from BRP	20,965,208	18,662,496	16,984,129	17,891,765	16,885,484	18,016,473	22,061,163	24,143,894	22,769,875	20,495,524	24,541,067	25,727,334	20,762,034
Total	Total rail transportation cost	13,707,542	12,385,427	13,626,913	13,261,462	13,683,354	13,269,525	13,763,982	13,796,234	13,374,342	13,723,668	13,366,279	13,836,548	13,482,940
	Total truck transportation cost	*29,326,655*	*26,214,770*	*25,345,577*	*25,983,488*	*25,246,932*	*26,108,196*	*30,422,610*	*32,505,342*	*30,861,598*	*28,856,971*	*32,632,791*	*34,088,781*	*28,966,143*
	Total transportation cost	**43,034,197**	**38,600,198**	**38,972,490**	**39,244,950**	**38,930,285**	**39,377,721**	**44,186,593**	**46,301,576**	**44,235,941**	**42,580,639**	**45,999,070**	**47,925,329**	**42,449,082**

Table C-1: Transportation Cost as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Appendix D

Transportation Cost per Unit Volume as a Result of the LP Model (No rail is added)

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	16,400	14,900	15,700	16,000	16,300	16,000	17,200	17,500	17,100	16,800	17,100	18,000	16,583
KKN	Total transportation cost (baht)	8,298,400	7,539,400	7,944,200	8,096,000	8,247,800	8,096,000	8,703,200	8,855,000	8,652,600	8,500,800	8,652,600	9,108,000	8,391,167
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	13,300	11,900	12,600	12,500	12,400	12,400	13,700	14,100	13,100	13,300	14,000	14,500	13,150
LMP	Total transportation cost (baht)	14,358,895	12,780,130	12,108,894	12,808,980	11,981,637	12,725,637	15,555,137	16,834,280	15,522,831	14,616,695	17,314,731	18,068,688	14,556,378
	Transportationcost / unit volume (baht/ton)	1,080	1,074	961	1,025	966	1,026	1,135	1,194	1,185	1,099	1,237	1,246	1,102
	Total volume transported (tons)	11,000	9,900	10,300	9,900	10,100	10,100	10,800	11,300	11,300	11,000	11,300	11,500	10,708
NSW	Total transportation cost (baht)	4,202,000	3,781,800	3,934,600	3,781,800	3,858,200	3,858,200	4,125,600	4,316,600	4,316,600	4,202,000	4,316,600	4,393,000	4,090,583
	Transportationcost / unit volume (baht/ton)	382	382	382	382	382	382	382	382	382	382	382	382	382
	Total volume transported (tons)	40,700	36,700	38,600	38,400	38,800	38,500	41,700	42,900	41,500	41,100	42,400	44,000	40,442
Total	Total transportation cost (baht)	26,859,295	24,101,330	23,987,694	24,686,780	24,087,637	24,679,837	28,383,937	30,005,880	28,492,031	27,319,495	30,283,931	31,569,688	27,038,128
	Transportationcost / unit volume (baht/ton)	660	657	621	643	621	641	681	699	687	665	714	717	667

Table D-1: Transportation Cost per Unit Volume as a Result of the LP Model as of 2001-2005 (No rail is added)

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	17,400	15,700	16,500	16,800	17,200	16,900	18,100	18,400	18,100	17,700	18,100	19,000	17,492
KKN	Total transportation cost (baht)	8,804,400	7,944,200	8,349,000	8,500,800	8,703,200	8,551,400	9,158,600	9,310,400	9,158,600	8,956,200	9,158,600	9,614,000	8,850,783
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	14,500	13,000	13,700	13,500	13,500	13,400	14,800	15,300	14,200	14,400	15,100	15,600	14,250
LMP	Total transportation cost (baht)	17,739,866	15,775,223	15,161,866	15,662,852	15,041,180	15,586,080	18,672,559	19,705,668	17,862,556	17,734,116	19,654,456	20,302,968	17,408,282
	Transportationcost / unit volume (baht/ton)	1,223	1,213	1,107	1,160	1,114	1,163	1,262	1,288	1,258	1,232	1,302	1,301	1,219
	Total volume transported (tons)	11,600	10,400	10,900	10,500	10,600	10,600	11,400	11,900	11,900	11,600	11,900	12,100	11,283
NSW	Total transportation cost (baht)	4,431,200	3,972,800	4,163,800	4,011,000	4,049,200	4,049,200	4,354,800	5,051,857	5,503,204	4,431,200	5,503,204	5,699,481	4,601,746
	Transportationcost / unit volume (baht/ton)	382	382	382	382	382	382	382	425	462	382	462	471	406
	Total volume transported (tons)	43,500	39,100	41,100	40,800	41,300	40,900	44,300	45,600	44,200	43,700	45,100	46,700	43,025
Total	Total transportation cost (baht)	30,975,466	27,692,223	27,674,666	28,174,652	27,793,580	28,186,680	32,185,959	34,067,924	32,524,360	31,121,516	34,316,260	35,616,449	30,860,811
	Transportationcost / unit volume (baht/ton)	712	708	673	691	673	689	727	747	736	712	761	763	716

Table D-1: Transportation Cost per Unit Volume as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	18,300	16,600	17,400	17,700	18,100	17,800	19,000	19,400	19,000	18,600	19,000	19,900	18,400
KKN	Total transportation cost (baht)	9,259,800	8,399,600	8,804,400	8,956,200	9,158,600	9,006,800	9,614,000	9,816,400	9,614,000	9,411,600	9,614,000	10,069,400	9,310,400
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	15,600	14,000	14,800	14,500	14,500	14,500	15,900	16,400	15,300	15,500	16,200	16,800	15,333
LMP	Total transportation cost (baht)	20,302,968	18,158,332	18,221,409	18,459,856	17,959,502	18,459,856	20,900,268	21,895,768	20,052,656	20,103,868	21,844,556	22,692,168	19,920,934
	Transportationcost / unit volume (baht/ton)	1,301	1,297	1,231	1,273	1,239	1,273	1,314	1,335	1,311	1,297	1,348	1,351	1,298
	Total volume transported (tons)	12,200	11,000	11,400	11,000	11,200	11,200	11,900	12,500	12,500	12,100	12,500	12,700	11,850
NSW	Total transportation cost (baht)	5,290,586	4,810,463	4,354,800	4,274,121	4,278,400	4,555,392	5,491,481	6,408,564	6,786,641	5,406,398	6,786,641	6,982,918	5,452,200
	Transportationcost / unit volume (baht/ton)	434	437	382	389	382	407	461	513	543	447	543	550	457
	Total volume transported (tons)	46,100	41,600	43,600	43,200	43,800	43,500	46,800	48,300	46,800	46,200	47,700	49,400	45,583
Total	Total transportation cost (baht)	34,853,353	31,368,395	31,380,609	31,690,177	31,396,502	32,022,048	36,005,749	38,120,731	36,453,297	34,921,866	38,245,197	39,744,485	34,683,534
	Transportationcost / unit volume (baht/ton)	756	754	720	734	717	736	769	789	779	756	802	805	760

Table D-1: Transportation Cost per Unit Volume as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	19,200	17,400	18,300	18,600	19,000	18,700	20,000	20,300	19,900	19,500	19,900	20,900	19,308
KKN	Total transportation cost (baht)	9,715,200	8,804,400	9,259,800	9,411,600	9,614,000	9,462,200	10,120,000	10,271,800	10,069,400	9,867,000	10,069,400	10,575,400	9,770,017
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	16,800	15,000	15,800	15,600	15,600	15,500	17,000	17,600	16,300	16,500	17,300	17,900	16,408
LMP	Total transportation cost (baht)	22,692,168	19,802,344	20,701,168	20,649,956	20,302,968	20,450,856	23,090,368	24,284,968	22,043,656	22,094,868	24,034,656	24,882,268	22,085,853
	Transportationcost / unit volume (baht/ton)	1,351	1,320	1,310	1,324	1,301	1,319	1,358	1,380	1,352	1,339	1,389	1,390	1,345
	Total volume transported (tons)	12,800	11,500	12,000	11,500	11,700	11,700	12,500	13,100	13,100	12,700	13,000	13,300	12,408
NSW	Total transportation cost (baht)	6,574,023	5,245,469	5,082,586	5,453,558	5,283,481	5,734,829	6,848,189	7,692,001	8,070,078	6,689,835	7,966,078	8,339,625	6,581,646
	Transportationcost / unit volume (baht/ton)	514	456	424	474	452	490	548	587	616	527	613	627	527
	Total volume transported (tons)	48,800	43,900	46,100	45,700	46,300	45,900	49,500	51,000	49,300	48,700	50,200	52,100	48,125
Total	Total transportation cost (baht)	38,981,390	33,852,213	35,043,553	35,515,114	35,200,449	35,647,884	40,058,556	42,248,768	40,183,133	38,651,702	42,070,133	43,797,293	38,437,516
	Transportationcost / unit volume (baht/ton)	799	771	760	777	760	777	809	828	815	794	838	841	797

Table D-1: Transportation Cost per Unit Volume as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
KKN	Total volume transported (tons)	20,200	18,300	19,200	19,500	19,900	19,600	20,900	21,300	20,900	20,400	20,800	21,800	20,233
	Total transportation cost (baht)	10,221,200	9,259,800	9,715,200	9,867,000	10,069,400	9,917,600	10,575,400	10,777,800	10,575,400	10,322,400	10,524,800	11,030,800	10,238,067
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
LMP	Total volume transported (tons)	17,900	16,000	16,900	16,600	16,600	16,500	18,200	18,700	17,400	17,600	18,400	19,100	17,492
	Total transportation cost (baht)	24,882,268	22,140,332	22,891,268	22,640,956	22,293,968	22,441,856	25,479,568	26,475,068	24,233,756	24,284,968	26,224,756	27,271,468	24,271,686
	Transportationcost / unit volume (baht/ton)	1,390	1,384	1,355	1,364	1,343	1,360	1,400	1,416	1,393	1,380	1,425	1,428	1,386
NSW	Total volume transported (tons)	13,400	12,100	12,600	12,100	12,300	12,300	13,100	13,700	13,700	13,300	13,600	13,900	13,008
	Total transportation cost (baht)	7,930,730	7,200,066	6,366,023	6,736,995	6,566,918	7,018,265	8,131,625	9,048,708	9,426,785	7,973,271	9,249,514	9,623,062	7,939,330
	Transportationcost / unit volume (baht/ton)	592	595	505	557	534	571	621	660	688	599	680	692	608
Total	Total volume transported (tons)	51,500	46,400	48,700	48,200	48,800	48,400	52,200	53,700	52,000	51,300	52,800	54,800	50,733
	Total transportation cost (baht)	43,034,197	38,600,198	38,972,490	39,244,950	38,930,285	39,377,721	44,186,593	46,301,576	44,235,941	42,580,639	45,999,070	47,925,329	42,449,082
	Transportationcost / unit volume (baht/ton)	836	832	800	814	798	814	846	862	851	830	871	875	836

Table D-1: Transportation Cost per Unit Volume as a Result of the LP Model as of 2001-2005 (No rail is added) (Cont.)

Appendix E

Deviation between Actual Demand and Planned Demand

Unit: tons

KKN 1999	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	13,600	13,200	12,900	12,600	12,800	13,100	13,700	12,900	14,800	15,100	14,100	14,600	13,616.67
Actual monthly demand	13,773	12,174	12,563	14,377	14,144	14,368	15,188	15,333	15,142	14,751	16,555	17,382	14,645.83
Working days	25	24	27	24	24	26	26	25	26	26	26	25	25.33
Planned daily demand	544	550	478	525	533	504	527	516	569	581	542	584	537.77
Actual daily demand	551	507	465	599	589	553	584	613	582	567	637	695	578.64
% different from plan	1.27	-7.77	-2.61	14.10	10.50	9.68	10.86	18.86	2.31	-2.31	17.41	19.05	7.61
Std. Dev. of actual daily demand	87.82	71.13	80.13	129.64	96.20	77.66	102.53	106.04	81.83	70.23	72.40	100.58	89.68
% of Std. Dev. from actual daily demand	15.94	14.02	17.22	21.64	16.32	14.05	17.55	17.29	14.05	12.38	11.37	14.47	15.53

Unit: tons

LMP 1999	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	10,500	10,300	10,000	9,300	9,400	10,300	11,200	12,100	11,500	11,700	12,200	11,900	10,866.67
Actual monthly demand	10,618	9,488	10,254	10,629	10,633	10,934	11,912	11,971	11,521	11,525	12,482	12,806	11,231.08
Working days	25	24	27	23	25	26	27	25	26	26	26	26	25.50
Planned daily demand	420	429	370	404	376	396	415	484	442	450	469	458	426.17
Actual daily demand	425	395	380	462	425	421	441	479	443	443	480	493	440.57
% different from plan	1.12	-7.88	2.54	14.29	13.12	6.16	6.36	-1.07	0.18	-1.50	2.31	7.61	3.60
Std. Dev. of actual daily demand	35.32	46.20	56.46	110.98	47.74	33.51	44.54	50.97	38.73	41.38	43.91	66.54	51.36
% of Std. Dev. from actual daily demand	8.32	11.69	14.87	24.01	11.22	7.97	10.10	10.64	8.74	9.34	9.15	13.51	11.63

Unit: tons

NSW 1999	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	8,800	8,400	8,800	8,200	8,600	8,900	10,000	9,300	10,900	11,200	10,900	11,200	9,600.00
Actual monthly demand	8,530	7,742	8,021	8,669	8,849	9,385	9,922	10,119	9,881	9,963	10,122	11,124	9,360.58
Working days	25	24	27	24	24	26	26	25	26	26	26	25	25.33
Planned daily demand	352	350	326	342	358	342	385	372	419	431	419	448	378.67
Actual daily demand	341	323	297	361	369	361	382	405	380	383	389	445	369.63
% different from plan	-3.07	-7.83	-8.85	5.72	2.90	5.45	-0.78	8.81	-9.35	-11.04	-7.14	-0.68	-2.16
Std. Dev. of actual daily demand	44.48	32.78	44.83	67.14	45.87	51.27	44.33	50.30	37.51	31.57	31.54	63.21	45.40
% of Std. Dev. from actual daily demand	13.04	10.16	15.09	18.59	12.44	14.20	11.62	12.43	9.87	8.24	8.10	14.21	12.33

Table E-1: KKN, LMP, and NSW Sales Data Summary as of 1999

Source: Depot Storage Management Division, Distribution Operation Department, Senior Vice President Supply Chain Management, PTT

Unit: tons

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
601	519	604	677	479	510	434	771	528	461	688	611
794	537	451	608	652	519	498	690	542	453	505	498
631	415	548	556	730	502	467	552	559	736	747	601
660	488	392	848	729	578	736	599	556	540	603	639
583	463	564	765	592	495	666	634	706	590	576	684
657	474	453	625	453	672	588	575	669	472	669	645
605	637	579	518	707	537	538	794	554	575	744	693
642	592	569	548	589	516	630	648	508	524	699	847
543	496	464	764	552	524	589	765	538	699	674	785
552	490	495	766	673	558	703	746	626	576	643	775
473	476	407	604	687	468	623	712	733	536	626	672
542	461	382	626	722	718	585	774	621	596	597	707
457	654	591	596	598	508	535	560	551	505	738	652
619	489	432	747	599	583	398	592	535	561	628	707
458	387	379	634	519	470	616	607	449	658	658	503
561	518	363	592	509	535	699	552	568	537	537	717
491	492	478	559	490	490	607	528	753	559	608	689
484	476	433	513	675	723	550	671	483	481	572	642
437	645	533	562	561	628	497	532	586	597	746	647
599	598	507	635	481	562	627	580	478	503	693	692
470	465	424	444	525	618	524	481	614	563	564	627
511	495	470	521	474	522	739	468	522	666	605	931
492	494	328	239	451	495	761	467	705	609	542	788
463	413	550	429	697	684	684	642	664	560	530	785
448		430			530	464	408	500	603	731	842
		354			426	428		591	590	641	
		354									

Table E-2: Raw Data of KKN Actual Demand as of 1999

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Unit: tons

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
449	442	501	454	435	456	375	497	463	396	528	444
501	387	408	508	431	363	385	437	401	474	573	415
480	425	390	498	507	374	503	441	420	498	492	465
431	321	395	648	468	441	461	439	454	479	461	507
388	385	436	558	430	430	421	493	510	450	423	521
461	422	428	486	507	470	482	510	498	391	515	495
445	470	440	512	440	432	404	528	427	434	493	417
457	437	428	561	479	378	396	508	446	512	523	450
403	413	380	658	343	365	452	574	393	464	438	485
422	349	295	626	372	384	527	529	424	373	425	552
404	321	377	466	403	454	422	555	472	439	456	509
424	475	481	463	434	449	426	540	442	422	505	566
431	408	396	526	436	447	449	445	440	429	524	435
456	326	361	424	468	399	424	504	368	475	463	448
409	383	384	395	386	367	454	423	421	483	447	456
417	401	304	366	417	428	508	413	526	457	406	517
379	399	375	427	363	432	455	549	440	379	498	522
427	453	446	400	411	406	390	469	474	454	498	561
400	446	465	465	477	410	451	485	420	387	546	443
416	396	351	337	417	392	429	431	383	461	485	438
478	345	329	369	417	423	475	368	412	456	477	425
390	332	336	240	356	440	529	457	469	448	388	642
381	376	343	243	352	448	449	452	498	451	500	606
352	378	317		391	474	376	489	422	368	486	593
419		290		492	466	390	432	445	430	492	523
		392			454	402		454	519	438	370
		268				475					

Table E-3: Raw Data of LMP Actual Demand as of 1999

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Unit: tons

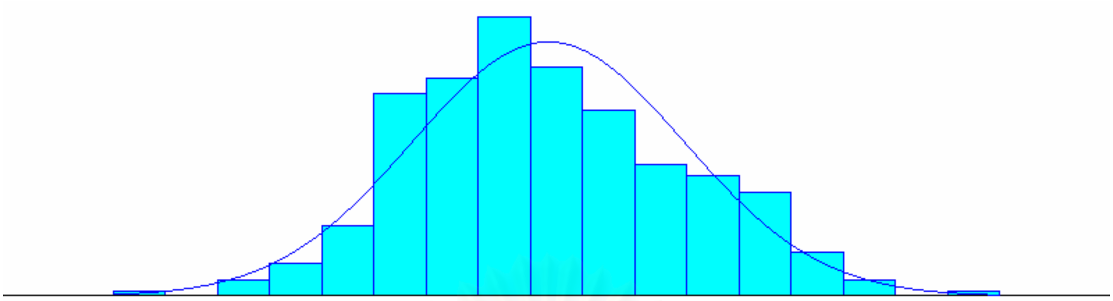
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
430	340	295	355	376	325	300	425	343	364	379	360
421	342	294	375	393	293	293	393	370	402	367	340
406	238	312	391	409	359	439	375	356	399	342	392
343	328	277	465	402	311	435	375	414	433	373	447
345	308	287	417	346	389	357	403	397	358	427	479
363	326	382	378	391	399	358	467	361	360	402	429
406	384	398	375	354	395	382	407	316	371	440	388
389	317	321	381	354	348	335	421	405	422	356	504
297	305	265	460	323	303	363	460	343	441	380	618
337	318	286	422	411	331	381	426	445	359	373	483
298	310	322	336	479	390	406	473	424	338	377	443
300	323	338	355	434	346	378	446	362	409	417	371
334	374	365	380	337	358	372	399	377	380	445	392
347	262	303	414	328	329	353	395	422	407	397	442
337	320	292	359	347	350	365	404	344	380	355	389
333	307	270	355	303	288	396	231	343	392	371	464
348	323	246	327	352	442	362	484	411	330	352	350
283	333	348	309	411	484	374	382	364	398	477	477
275	360	356	450	298	474	340	440	378	412	392	443
378	344	250	379	315	376	381	331	316	342	366	429
283	325	267	291	391	376	380	399	323	395	397	458
313	259	336	308	310	350	408	354	459	350	376	494
304	327	302	162	352	339	470	404	413	404	375	535
304	359	242	242	423	359	387	427	347	337	411	501
356		236			386	408	390	393	355	392	485
		261			285	493		361	417	378	
		203									

Table E-4: Raw Data of NSW Actual Demand as of 1999

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

KKN Sales Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (600, 93.18)

Square Error: 0.004355

Chi Square Test

Number of intervals = 11

Degrees of freedom = 8

Test Statistic = 15.3

Corresponding p-value = 0.0549

Kolmogorov-Smirnov Test

Test Statistic = 0.0474

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 304

Min Data Value = 239

Max Data Value = 931

Sample Mean = 578

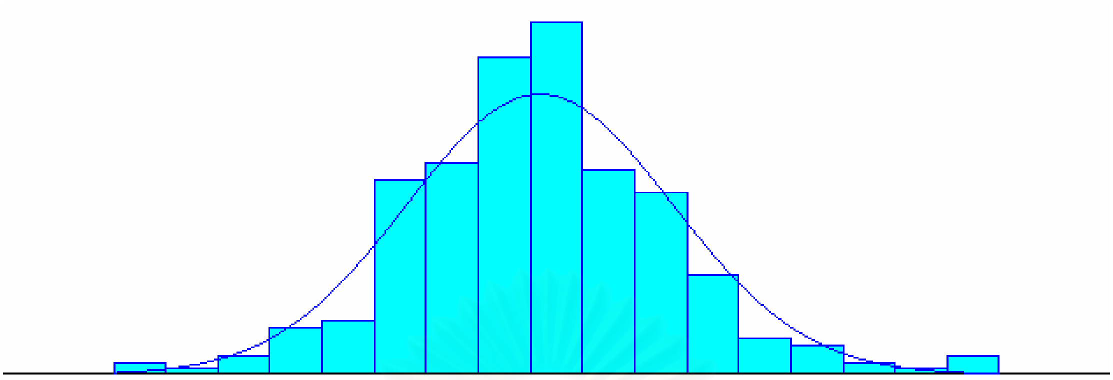
Sample Std Dev = 106

Histogram Summary

Histogram Range = 239 to 931

Number of Intervals = 17

LMP Sales Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (467,54.31)

Square Error: 0.004581

Chi Square Test

Number of intervals = 10

Degrees of freedom = 7

Test Statistic = 14.9

Corresponding p-value = 0.0397

Kolmogorov-Smirnov Test

Test Statistic = 0.0524

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 306

Min Data Value = 240

Max Data Value = 658

Sample Mean = 441

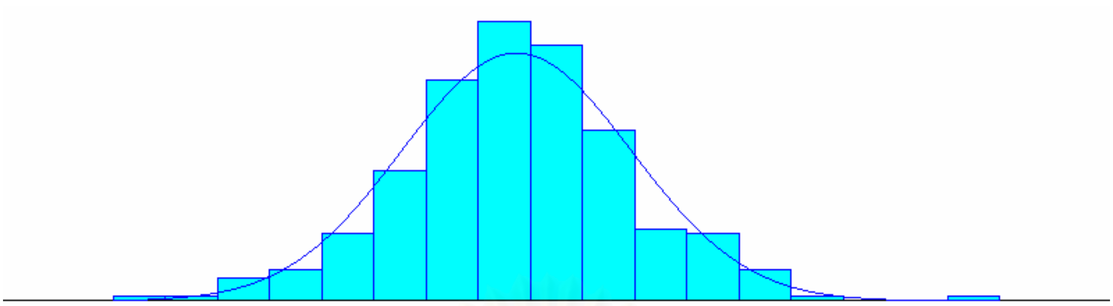
Sample Std Dev = 62.9

Histogram Summary

Histogram Range = 240 to 658

Number of Intervals = 17

NSW Sales Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (393, 48.46)

Square Error: 0.002441

Chi Square Test

Number of intervals = 9

Degrees of freedom = 6

Test Statistic = 7.31

Corresponding p-value = 0.303

Kolmogorov-Smirnov Test

Test Statistic = 0.0368

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 304

Min Data Value = 162

Max Data Value = 618

Sample Mean = 369

Sample Std Dev = 59.1

Histogram Summary

Histogram Range = 162 to 618

Number of Intervals = 17

Appendix F

Transportation Lead Time

Unit: minutes

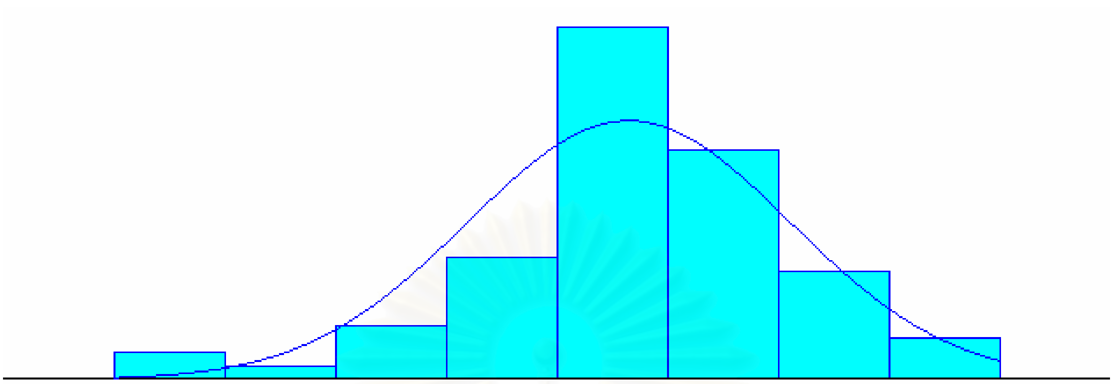
BRP-KKN		KKN-BRP		BRP-LMP	LMP-BRP	BRP-NSW	NSW-BRP
932	874	888	638	1457	1235	487	658
793	865	727	774	1667	1365	682	696
942	905	823	857	1500	1275	673	704
923	820	642	844	1921	1223	700	694
855	905	623	899	1475	1487	715	822
829	903	685	719	1631	1196	732	673
973	863	766	542	1715	1280	635	767
666	850	791	788	1555	1120	658	885
1017	880	871	843	1801	1366	485	757
798	889	953	739	1704	1269	524	772
990	1052	726	678	1433	998	730	664
820	775	771	774	1633	1198	672	632
836	975	641	752	1588	1153	641	781
745	961	831	733	1723	1288	767	670
848	932	699	776	1600	1165	664	755
851	848	804	833	1662	1227	642	780
765	902	885	854	1750	1315	767	855
858	728	689	694	1512	1077	664	668
633	860	694	843	1688	1253	642	744
851	940	798	771	1704	1269	741	777
980	923	557	780	1517	1082	726	704
778	880	679	717	1593	1158	642	750
860	909	899	610	1707	1272	767	723
849	860	677	834	1675	1240	664	855
1043	890	766	699	1769	1334	651	793
902	930	659	659	1664	1229	534	855
900	880	677	655	1582	1147	757	772
847	865	627	608	1796	1361	802	828
971	845	794	723	1727	1292	520	687
862	800	619	519			506	688
827	845	649	773			739	736
843	930	739	766			580	671
975	825	678	647			721	746
961	936	774	844			726	807
875	903	890	899				

Table F-1: Raw Data of Rail Transportation Lead Time (March - May, 2000)

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Rail Lead Time to from BRP to KKN Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (876, 76.4)

Square Error: 0.018384

Chi Square Test

Number of intervals = 5

Degrees of freedom = 2

Test Statistic = 5.22

Corresponding p-value = 0.0777

Kolmogorov-Smirnov Test

Test Statistic = 0.102

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 70

Min Data Value = 633

Max Data Value = 1.05e+003

Sample Mean = 876

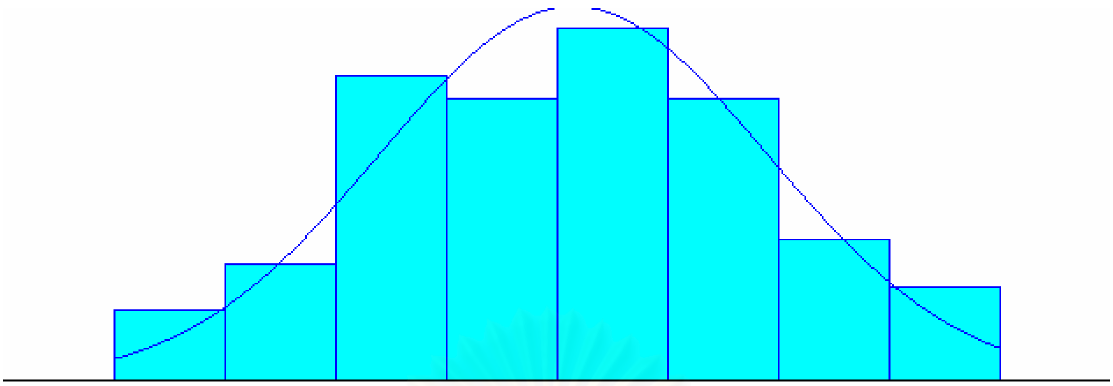
Sample Std Dev = 77

Histogram Summary

Histogram Range = 633 to 1.05e+003

Number of Intervals = 8

Rail Lead Time to from KKN to BRP Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (744, 94.9)

Square Error: 0.003836

Chi Square Test

Number of intervals = 6

Degrees of freedom = 3

Test Statistic = 1.47

Corresponding p-value = 0.693

Kolmogorov-Smirnov Test

Test Statistic = 0.0688

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 70

Min Data Value = 519

Max Data Value = 953

Sample Mean = 744

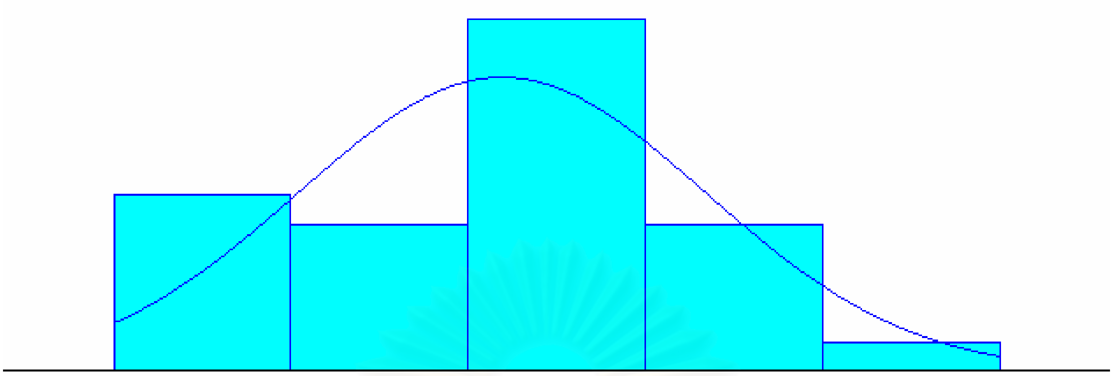
Sample Std Dev = 95.6

Histogram Summary

Histogram Range = 519 to 953

Number of Intervals = 8

Rail Lead Time from BRP to LMP Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (1.65e+003, 112)

Square Error: 0.027938

Chi Square Test

Number of intervals = 3

Degrees of freedom = 0

Test Statistic = 0.87

Corresponding p-value < 0.005

Kolmogorov-Smirnov Test

Test Statistic = 0.111

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 29

Min Data Value = 1.43e+003

Max Data Value = 1.92e+003

Sample Mean = 1.65e+003

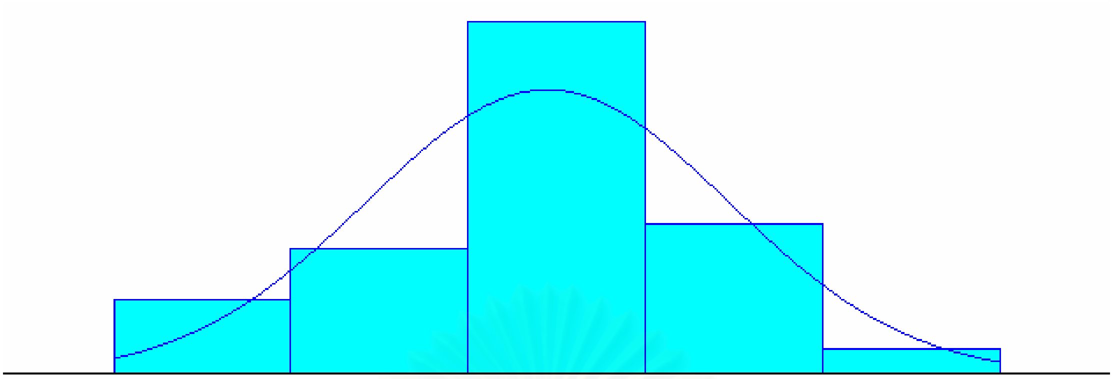
Sample Std Dev = 114

Histogram Summary

Histogram Range = 1.43e+003 to 1.92e+003

Number of Intervals = 5

Rail Lead Time from LMP to BRP Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (1.24e+003, 99.9)

Square Error: 0.020269

Chi Square Test

Number of intervals = 3

Degrees of freedom = 0

Test Statistic = 1.38

Corresponding p-value < 0.005

Kolmogorov-Smirnov Test

Test Statistic = 0.0926

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 29

Min Data Value = 998

Max Data Value = 1.49e+003

Sample Mean = 1.24e+003

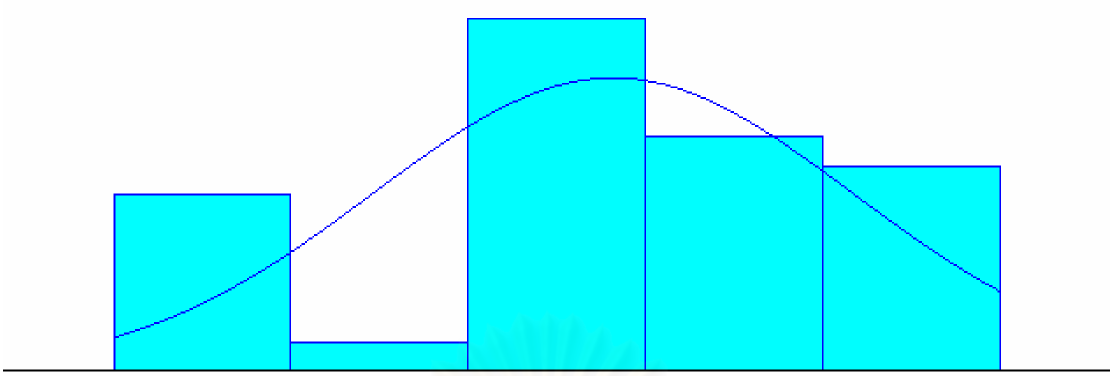
Sample Std Dev = 102

Histogram Summary

Histogram Range = 998 to 1.49e+003

Number of Intervals = 5

Rail Lead Time from BRP to NSW Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (663, 85.9)

Square Error: 0.045138

Chi Square Test

Number of intervals = 3

Degrees of freedom = 0

Test Statistic = 1.22

Corresponding p-value < 0.005

Kolmogorov-Smirnov Test

Test Statistic = 0.146

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 34

Min Data Value = 485

Max Data Value = 802

Sample Mean = 663

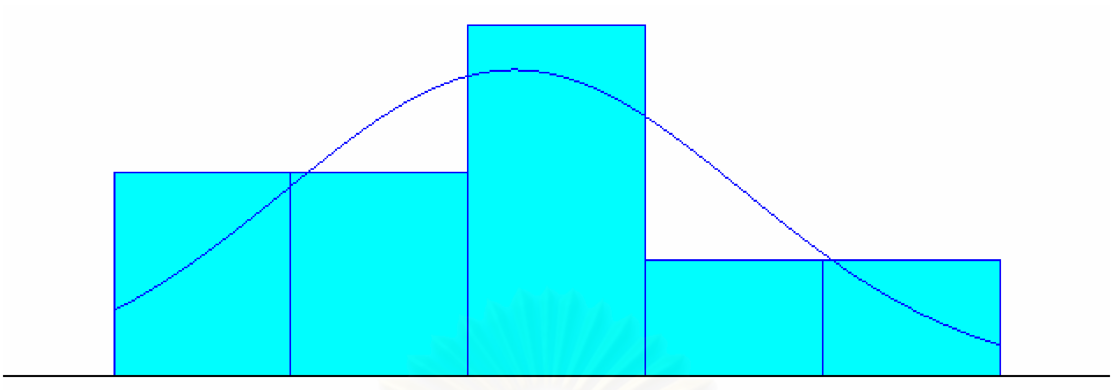
Sample Std Dev = 87.2

Histogram Summary

Histogram Range = 485 to 802

Number of Intervals = 5

Rail Lead Time from NSW to BRP Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (746, 65.4)

Square Error: 0.020175

Chi Square Test

Number of intervals = 3

Degrees of freedom = 0

Test Statistic = 1.59

Corresponding p-value < 0.005

Kolmogorov-Smirnov Test

Test Statistic = 0.138

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 34

Min Data Value = 632

Max Data Value = 885

Sample Mean = 746

Sample Std Dev = 66.3

Histogram Summary

Histogram Range = 632 to 885

Number of Intervals = 5

Unit: minutes

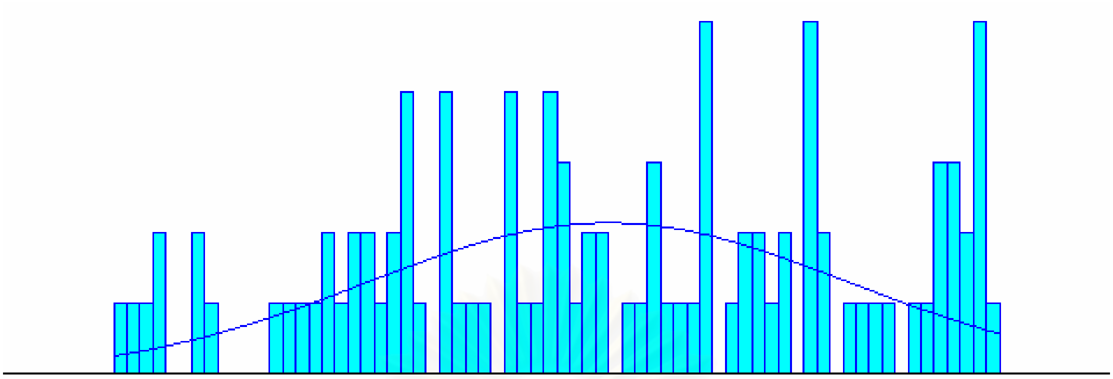
BRP-LMP			LKB-LMP		
932	964	990	327	317	305
985	994	989	327	293	275
952	997	953	318	299	338
984	974	938	314	323	294
980	966	947	299	311	291
952	995	961	316	312	317
957	979	965	333	323	289
953	979	937	314	309	321
996	965	937	310	283	294
964	971	958	281	325	338
987	967	959	331	337	282
994	956	944	313	310	279
951	961	949	337	310	277
997	956	984	319	301	290
956	996	994	330	300	286
961	992	947	303	337	301
962	964	933	290	301	308
982	984	972	299	309	311
981	956	954	292	298	308
978	934	976	282	277	321
972	950	988	300	305	293
968	948	976	290	333	292
976	968	949	292	308	337
997	970	980	318	302	291
984	967	945	313	280	328
950	997	984	282	303	301
961	963	993	273	273	316
982	943	985	336	299	321
995	931	953	295	282	317
995	975	973	290	275	321
997	953	934	292	291	326
965	976	946	279	279	309
998	964		336	312	
972	976		328	302	

Table F-2: Raw Data of Truck Transportation Lead Time (March - May, 2000)

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Truck Lead Time in Fleet of BRP to LMP Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (968, 18.5)

Square Error: 0.011763

Chi Square Test

Number of intervals = 8

Degrees of freedom = 5

Test Statistic = 9.69

Corresponding p-value = 0.0876

Data Summary

Number of Data Points = 100

Min Data Value = 931

Max Data Value = 998

Sample Mean = 968

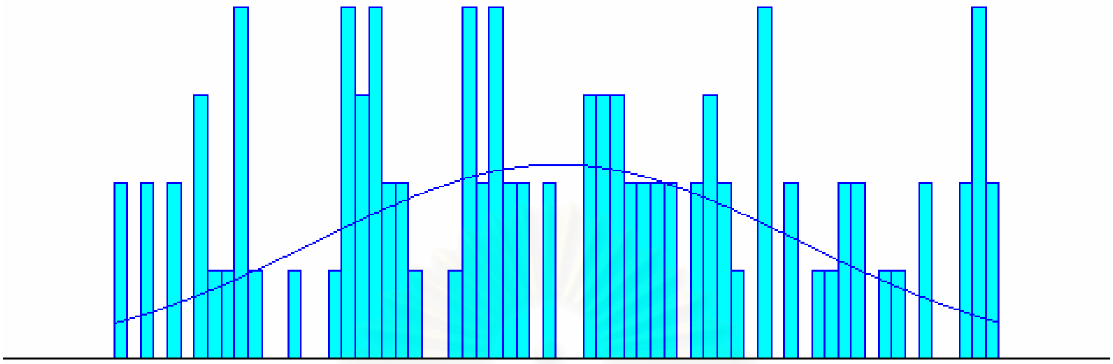
Sample Std Dev = 18.6

Histogram Summary

Histogram Range = 931 to 999

Number of Intervals = 68

Truck Lead Time from GSP LKB to LMP Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (306, 18)

Square Error: 0.011685

Chi Square Test

Number of intervals = 8

Degrees of freedom = 5

Test Statistic = 10.1

Corresponding p-value = 0.0771

Data Summary

Number of Data Points = 100

Min Data Value = 273

Max Data Value = 338

Sample Mean = 306

Sample Std Dev = 18.1

Histogram Summary

Histogram Range = 273 to 339

Number of Intervals = 66

Appendix G

Failure Rate

Unit: minutes

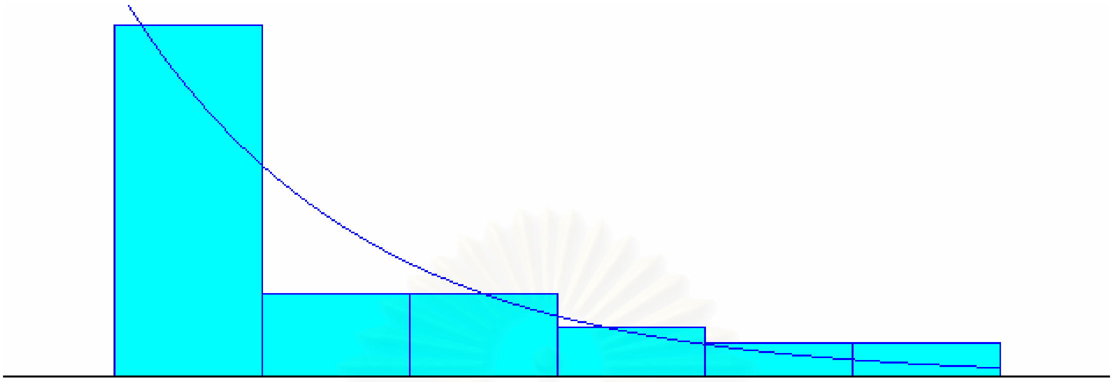
Rail		Truck	
Frequency	**Duration**	**Frequency**	**Duration**
181440	705	1440	2880
25920	1098	1440	2880
224640	312	1440	4320
38880	2880	1440	720
12960	897	5760	1440
1440	965	1440	2880
25920	295	2880	7200
118080	240	5760	7200
37440	765	1440	18720
2880	300	2880	15840
220320	153	7200	1440
177120	145	5760	1440
31680	95	1440	720
18720	262		
37440	990		
27360	380		
106560	1083		
43200	1440		
10080	265		
51840	2040		
23040	1440		
70560	720		
144000	420		
41760	628		
106560	1445		
142560	205		
5760	735		
112320	78		
89280	320		
7200	290		
5760	345		
11520	164		
31680	800		
17280	230		
18720	480		
1440	770		
28800	515		
80640	358		
	1130		

Table G-1: Raw Data of Rail and Truck Failure Frequency and Failure Duration (1996 - June, 2000)

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Rail Frequency of Failure



Distribution Summary

Distribution: Exponential

Expression: 1.44e+003 + EXPO(5.99e+004)

Square Error: 0.023108

Chi Square Test

Number of intervals = 3

Degrees of freedom = 1

Test Statistic = 3.14

Corresponding p-value = 0.0811

Kolmogorov-Smirnov Test

Test Statistic = 0.13

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 38

Min Data Value = 1.44e+003

Max Data Value = 2.25e+005

Sample Mean = 6.14e+004

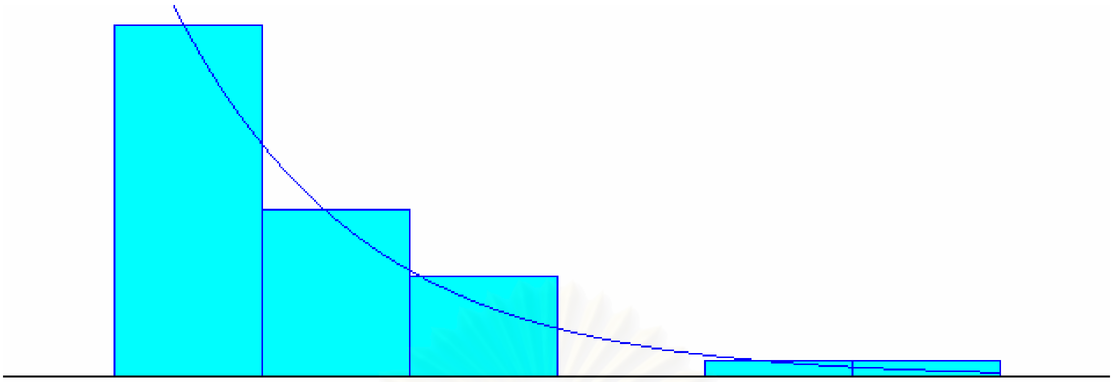
Sample Std Dev = 6.31e+004

Histogram Summary

Histogram Range = 1.44e+003 to 2.25e+005

Number of Intervals = 6

Rail Duration of Failure



Distribution Summary

Distribution: Exponential

Expression: 78 + EXPO (598)

Square Error: 0.004620

Chi Square Test

Number of intervals = 3

Degrees of freedom = 1

Test Statistic = 0.0491

Corresponding p-value > 0.75

Kolmogorov-Smirnov Test

Test Statistic = 0.0851

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 39

Min Data Value = 78

Max Data Value = 2.88e+003

Sample Mean = 676

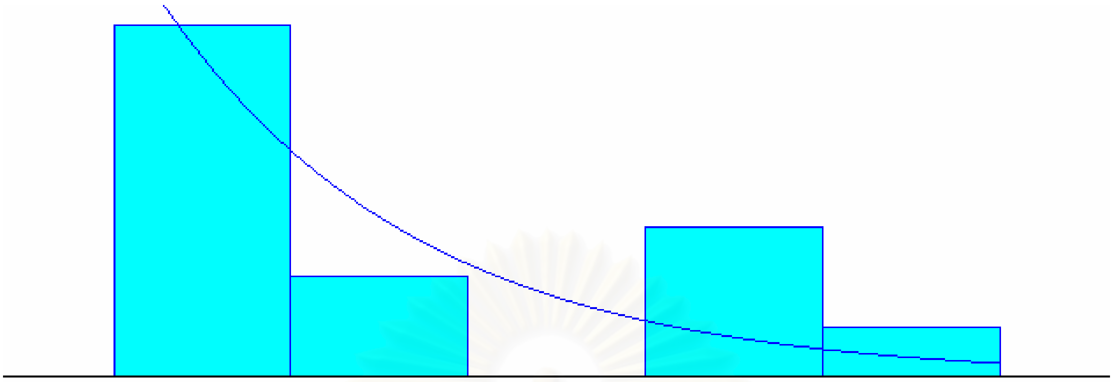
Sample Std Dev = 582

Histogram Summary

Histogram Range = 78 to 2.88e+003

Number of Intervals = 6

Truck Frequency of Failure



Distribution Summary

Distribution: Exponential

Expression: 1.44e+003 + EXPO (1.66e+003)

Square Error: 0.056747

Kolmogorov-Smirnov Test

Test Statistic = 0.233

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 13

Min Data Value = 1.44e+003

Max Data Value = 7.2e+003

Sample Mean = 3.1e+003

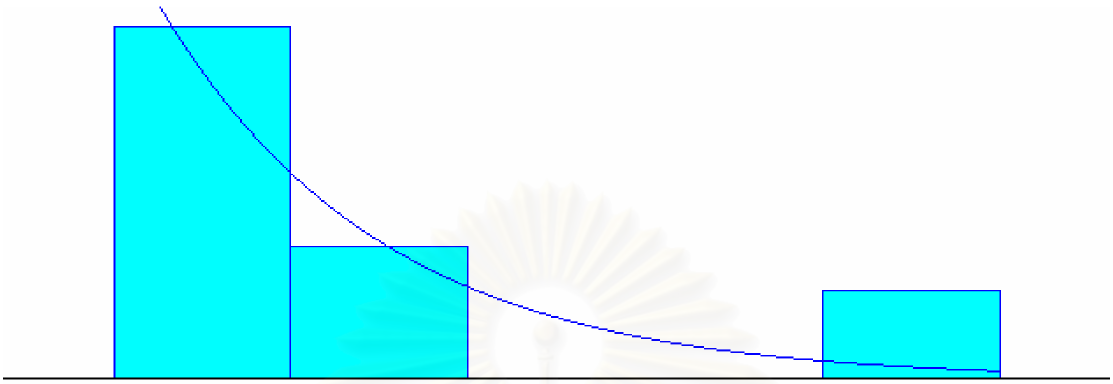
Sample Std Dev = 2.19e+003

Histogram Summary

Histogram Range = 1.44e+003 to 7.2e+003

Number of Intervals = 5

Truck Duration of Failure



Distribution Summary

Distribution: Exponential

Expression: 720 + EXPO (4.49e+003)

Square Error: 0.036389

Kolmogorov-Smirnov Test

Test Statistic = 0.141

Corresponding p-value > 0.15

Data Summary

Number of Data Points = 13

Min Data Value = 720

Max Data Value = 1.87e+004

Sample Mean = 5.21e+003

Sample Std Dev = 5.8e+003

Histogram Summary

Histogram Range = 720 to 1.87e+004

Number of Intervals = 5

Appendix H

Loading Time

Unit: minutes

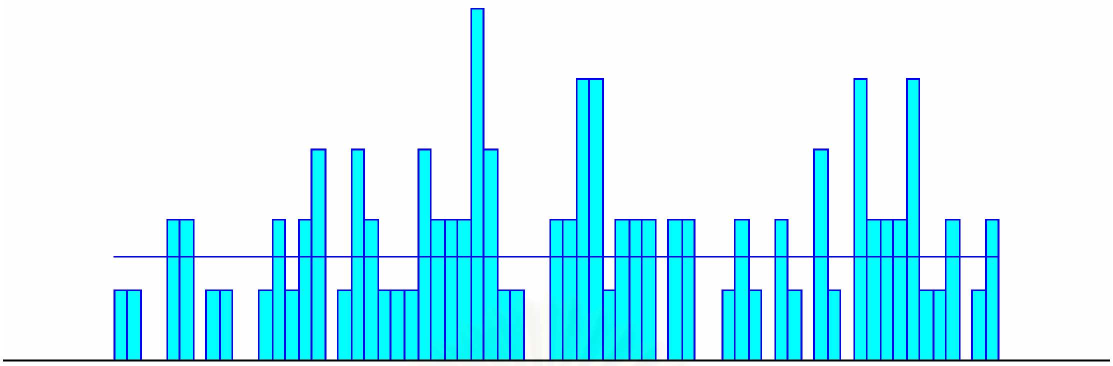
Rail loading time at BRP			Truck loading time at BRP			Truck loading time at GSP LKB		
305	306	274	40	43	43	53	59	51
282	285	328	47	42	40	55	54	58
327	305	306	45	43	41	52	56	54
326	296	293	41	42	48	54	51	52
270	305	297	49	41	48	50	51	56
277	326	336	40	49	42	53	52	52
306	330	320	42	42	41	52	57	56
317	289	331	47	43	48	50	54	59
323	300	320	44	49	43	54	58	59
296	312	298	47	47	41	51	58	52
323	283	328	47	45	41	55	54	54
297	307	333	40	45	49	59	55	56
282	327	288	44	46	40	50	58	55
303	285	336	46	44	47	52	50	53
285	284	335	46	42	48	54	54	52
278	323	299	43	44	40	53	58	54
297	298	326	40	41	45	54	53	56
332	293	308	42	40	43	56	56	51
310	288	292	47	43	45	56	57	55
329	294	324	44	42	45	56	55	56
326	294	284	41	42	47	58	51	52
312	297	288	45	45	45	58	52	51
330	274	330	44	40	49	55	50	54
333	287	275	49	47	43	50	56	54
271	293	290	46	48	41	50	55	57
316	304	330	47	46	43	56	58	51
305	308	298	42	47	49	51	54	55
318	309	295	44	49	48	56	54	54
313	295	281	49	42	46	59	56	59
317	321	304	42	47	47	56	53	57
275	303	297	43	41	45	56	54	52
310	309	306	40	45	48	50	54	51
291	289		40	49		56	54	
329	313		43	44		58	53	

Table H-1: Raw Data of Loading Time (January - May, 2000)

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Rail Loading Time Fitted Curve and Expression



Distribution Summary

Distribution: Uniform

Expression: UNIF (max, min): UNIF (270, 337)

UNIF (mean, half range): UNIF (303, 33)

Square Error: 0.009275

Chi Square Test

Number of intervals = 9

Degrees of freedom = 8

Test Statistic = 15.1

Corresponding p-value = 0.0597

Data Summary

Number of Data Points = 100

Min Data Value = 270

Max Data Value = 336

Sample Mean = 305

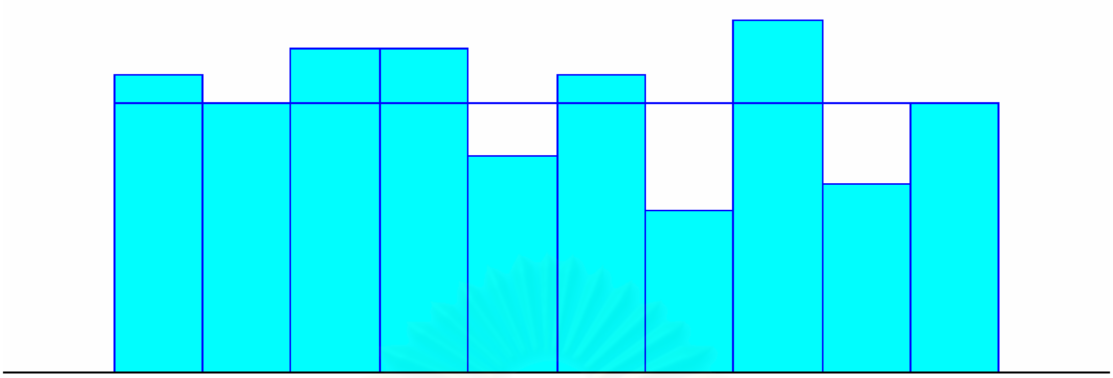
Sample Std Dev = 17.9

Histogram Summary

Histogram Range = 270 to 337

Number of Intervals = 67

Truck Loading Time at BRP Fitted Curve and Expression



Distribution Summary

Distribution: Uniform

Expression: UNIF (max, min): UNIF (39.5, 49.5)

UNIF (mean, half range): UNIF (44.5, 4.5)

Square Error: 0.004800

Chi Square Test

Number of intervals = 6

Degrees of freedom = 5

Test Statistic = 1.45

Corresponding p-value > 0.75

Data Summary

Number of Data Points = 100

Min Data Value = 40

Max Data Value = 49

Sample Mean = 44.3

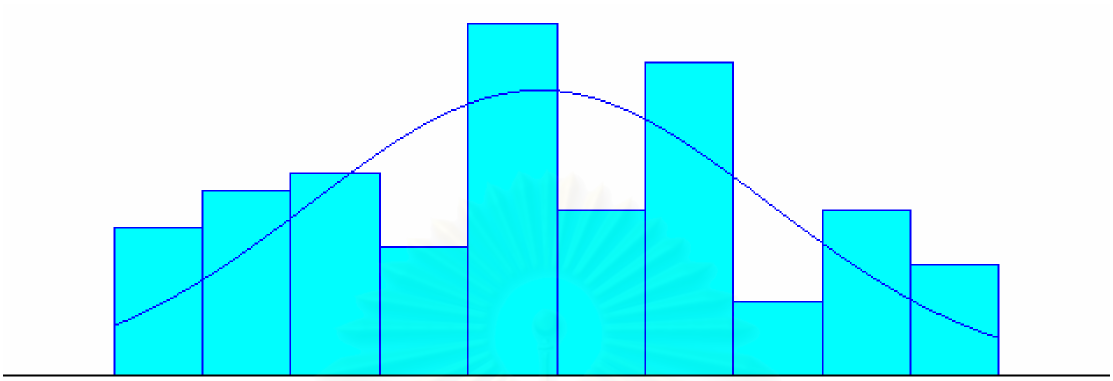
Sample Std Dev = 2.9

Histogram Summary

Histogram Range = 39.5 to 49.5

Number of Intervals = 10

Truck Loading Time at GSP LKB Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (54.3, 2.58)

Square Error: 0.018416

Chi Square Test

Number of intervals = 7

Degrees of freedom = 4

Test Statistic = 13.3

Corresponding p-value = 0.0101

Data Summary

Number of Data Points = 100

Min Data Value = 50

Max Data Value = 59

Sample Mean = 54.3

Sample Std Dev = 2.6

Histogram Summary

Histogram Range = 49.5 to 59.5

Number of Intervals = 10

Appendix I

Unloading Time

Unit: minutes

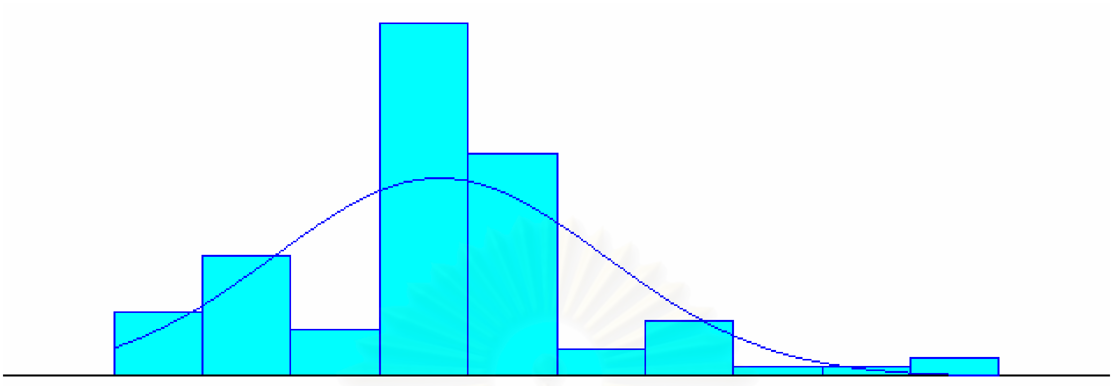
Rail loading time at BRP			Truck unloading time		
510	510	450	64	58	64
480	510	500	62	59	57
480	480	550	58	59	57
570	480	510	62	58	59
510	480	480	59	58	61
600	420	480	59	60	63
480	480	525	59	61	62
480	480	480	62	60	59
480	510	540	64	57	63
450	480	480	64	58	55
510	480	510	59	64	61
510	460	480	60	55	57
450	520	510	61	64	64
480	480	450	58	64	62
480	510	450	59	55	57
540	420	515	58	61	63
430	450	420	62	60	56
480	540	505	62	62	64
480	430	450	58	57	60
480	500	480	62	63	60
495	450	470	64	60	64
510	470	540	63	58	64
480	480	510	57	64	63
505	480	460	58	61	61
540	500	480	55	59	59
480	480	480	58	57	61
420	450	495	61	58	56
480	500	450	64	60	55
480	480	470	60	56	55
450	480	480	55	62	55
450	495	495	58	58	63
420	480	585	59	56	64
500	480		57	59	
450	540		62	58	

Table I-1: Raw Data of Rail and Truck Unloading Time (January-May,2000)

Source: Depot Storage Management Division, Distribution Operation Department,

Senior Vice President Supply Chain Management, PTT

Rail Unloading Time Fitted Curve and Expression



Distribution Summary

Distribution: Normal

Expression: NORM (486, 33.6)

Square Error: 0.058457

Chi Square Test

Number of intervals = 6

Degrees of freedom = 3

Test Statistic = 33.2

Corresponding p-value < 0.005

Kolmogorov-Smirnov Test

Test Statistic = 0.158

Corresponding p-value = 0.0124

Data Summary

Number of Data Points = 100

Min Data Value = 420

Max Data Value = 600

Sample Mean = 486

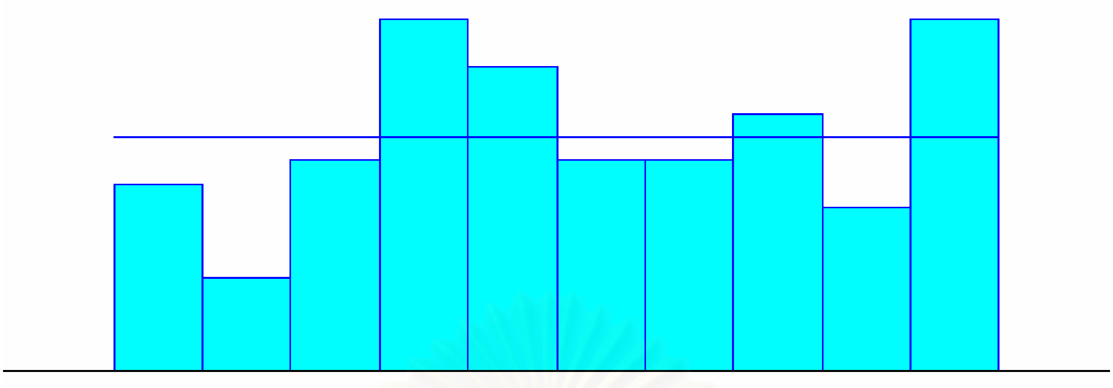
Sample Std Dev = 33.8

Histogram Summary

Histogram Range = 420 to 600

Number of Intervals = 10

Truck Unloading Time Fitted Curve and Expression



Distribution Summary

Distribution: Uniform

Expression: UNIF (max, min): UNIF (54.5, 64.5)

UNIF (mean, half range): UNIF (59.5, 4.5)

Square Error: 0.011200

Chi Square Test

Number of intervals = 6

Degrees of freedom = 5

Test Statistic = 5.2

Corresponding p-value = 0.407

Data Summary

Number of Data Points = 100

Min Data Value = 55

Max Data Value = 64

Sample Mean = 59.9

Sample Std Dev = 2.79

Histogram Summary

Histogram Range = 54.5 to 64.5

Number of Intervals = 10

Appendix J

A Base Line Simulation Model

ProModel model: MAR2000

*LPG DISTRIBUTION SYSTEM

FUNCTIONS AND DISTRIBUTIONS

D1

N 600,93.18

D2

N 467,54.31

D3

N 393,48.46

D4

U 303,33

D5

U 44.5,4.5

D6

N 54.3,2.58

D7

N 486,33.6

D8

U 59.5,4.5

D9

E 59900

D10

E 598

D11

E 1660

D12

E 4490

ROUTING

```
                        Output  Next      Condi-    Move
Part  Location Operation (min)    part  location   tion Qty  time (min)
----  -------- ---------------    ----  --------   ---- ---  ----------
A     DUMMY1   V46=9100           A     EXIT       0    1    0
               V47=31
               V86=27
               V43=16200
               V44=12600
               V45=10600
               V111=600
               V112=467
               V113=393
```

```
V175=5
VR1=1780
VR2=1100
VR3=1500
V94=2000,TRACK
V95=800,TRACK
V13=458
V14=458
V15=510
V48=16
V157=801
V158=601
V165=6
V49=V43+V45
V50=V49+V44
V61=0,TRACK
IF V47<30,+3
V87=V175*7000
+2
V87=V175*6625
V88=V87+1
V105=10
V106=10
V107=10
IF V43<V88,+4
V52=V43-V87
VR16=V52/V47
+2
VR16=0
IF V43>V87,+8
V53=V87-V43
IF V45<V53 OR V45=
V53,+4
V54=V45-V53
VR18=V54/V47
+4
VR18=0
+2
VR18=V45/V47
IF V44<V46 OR V44=
V46,+8
V55=V44-V46
IF V49>V87,+8
```

```
V56=V87-V49
IF V55<V56,+4
V57=V55-V56
VR17=V57/V47
+4
VR17=0
+2
VR17=V55/V47
VR19=0
VR20=V46/V47
VR21=0
V62=VR16+VR17
V63=V62+VR18
V64=VR19+VR20
V65=V64+VR21
VR9=VR16/V48
V80=VR16/V48
IF VR9<>V80,+3
V72=V80
+2
V72=V80+1
VR10=VR17/V48
V81=VR17/V48
IF VR10<>V81,+3
V73=V81
+2
V73=V81+1
VR11=VR18/V48
V82=VR18/V48
IF VR11<>V82,+3
V74=V82
+2
V74=V82+1
VR12=VR19/V48
V83=VR19/V48
IF VR12<>V83,+3
V75=V83
+2
V75=V83+1
VR13=VR20/V48
V84=VR20/V48
IF VR13<>V84,+3
V76=V84
```

```
+2
V76=V84+1
VR14=VR21/V48
V85=VR21/V48
IF VR14<>V85,+3
V77=V85
+2
V77=V85+1
V96=0,TRACK
V97=0,TRACK
V98=0,TRACK
V99=0,TRACK
V100=0,TRACK
V101=0,TRACK
V102=0,TRACK
V103=0,TRACK
V104=0,TRACK
V16=V72+V75
V17=V73+V76
V18=V74+V77
V114=V16*V48
V115=V17*V48
V116=V18*V48
V19=V75*V48
V20=V76*V48
V21=V77*V48
V117=0,TRACK
V118=0,TRACK
V119=0,TRACK
V120=0,TRACK
V93=1000
V125=1000
V126=1000
V127=1000
V128=1000
V129=1000
VR4=V175/2
V176=V175/2
IF VR4>V176,+3
V177=0
+2
V177=1
V178=V176+V177
```

```
A    DUMMY20  V179=1          A    EXIT      0   1   0
          24::
          V179=2
          24::
          -4
A    DUMMY21  V184=0          A    EXIT      0   1   0
          IF V179=1,+3
          V180=V176
          +2
          V180=V178
          IF V68=0,END
          V69=V69+1
          IF V69=2,+3
          IF V69=3,+4
          END
          V180=V180-1
          END
          V180=V180-1
          V68=0
          V69=0
          END
A    DUMMY2   V79=0           A    EXIT      0   1   0
          V73=V73-V161
          V74=V74-V164
          V161=0
          V164=0
          V92=V92+1,TRACK
          V58=V58+1
          IF V58=6,+5
          V10=V111
          V11=V112
          V12=V113
          +4
          V10=0
          V11=0
          V12=0
          IF V58=7,+8
          V7=V111
          V8=V112
          V9=V113
          V108=D1
          V109=D2
          V110=D3
```

```
+8
V7=0
V8=0
V9=0
V108=0
V109=0
V110=0
V58=0
VR6=V108/V105
VR7=V109/V106
VR8=V110/V107
V117=V117+V108
V118=V118+V109
V119=V119+V110
V1=VR1
V2=VR2
V3=VR3
V22=V1-V7
V23=V22+V4
V24=V23+V19
V25=V24-V10
V26=V25+V13
V27=V26+V114
V28=V2-V8
V29=V28+V5
V30=V29+V20
V31=V30-V11
V32=V31+V14
V33=V32+V115
V34=V3-V9
V35=V34+V6
V36=V35+V116
V37=V36-V12
V38=V37+V15
V39=V38+V116
IF V2<V157,+2
+5
V159=V157-V2
V160=V159/V165
V161=V160/V48
V73=V73+V161
IF V3<V158,+2
+5
```

```
        V162=V158-V3
        V163=V162/V165
        V164=V163/V48
        V74=V74+V164
        0:01
        V4=0
        V5=0
        V6=0
A   DUMMY3  V51=1       A   EXIT    0  1  0
        16::
        V51=0
        8::
        -4
A   DUMMY4  V66=1       A   EXIT    0  1  0
        10::
        V66=0
        14::
        -4
A   DUMMY5  V67=1       A   EXIT    0  1  0
        16::
        V67=0
        8::
        -4
A   DUMMY6  V121=1      A   EXIT    0  1  0
        10::
        V121=0
        14::
        -4
A   DUMMY7  V122=1      A   EXIT    0  1  0
        16::
        V122=0
        8::
        -4
A   DUMMY8  V123=1      A   EXIT    0  1  0
        10::
        V123=0
        14::
        -4
A   DUMMY9  V124=1      A   EXIT    0  1  0
        16::
        V124=0
        8::
        -4
```

```
LPG   DUMMY10  0               IF V72=0,END
                     LPG   BRPTK     0    V72  0
LPG   BRPTK    IF V51=0,WAIT      V96=V96+1
          GET TRUCK1        V61=V61+V48
          USE OPER2 D5      V4=V4+V48
                     V94=V94-V48
                     LPG   KKNT1     0    1    TRUCK1
LPG   DUMMY11  0               IF V73=0,END
                     LPG   BRPTL     0    V73  0
LPG   BRPTL    IF V51=0,WAIT      V97=V97+1
          GET TRUCK1        V61=V61+V48
          USE OPER2 D5      V5=V5+V48
                     V94=V94-V48
                     LPG   LMPT1     0    1    TRUCK1
LPG   DUMMY12  0               IF V74=0,END
                     LPG   BRPTN     0    V74  0
LPG   BRPTN    IF V51=0,WAIT      V98=V98+1
          GET TRUCK1        V61=V61+V48
          USE OPER2 D5      V94=V94-V48
                     LPG   NSWT1     0    1    TRUCK1
LPG   DUMMY13  0               IF V75=0,END
                     LPG   LKBTK     0    V75  0
LPG   LKBTK    GET TRUCK2        V99=V99+1
          USE OPER3 D6      V95=V95-V48
                     V120=V120+V48
                     LPG   KKNT2     0    1    TRUCK2
LPG   DUMMY14  0               IF V76=0,END
                     LPG   LKBTL     0    V76  0
LPG   LKBTL    GET TRUCK2        V100=V100+1
          USE OPER3 D6      V95=V95-V48
                     V120=V120+V48
                     LPG   LMPT2     0    1    TRUCK2
LPG   DUMMY15  0               IF V77=0,END
                     LPG   LKBTN     0    V77  0
LPG   LKBTN    GET TRUCK2        V101=V101+1
          USE OPER3 D6      V95=V95-V48
                     V120=V120+V48
                     LPG   NSWT2     0    1    TRUCK2
LPG   BRPRAIL  IF V51=0,WAIT      IF AT1=0,END
          V184=V184+1       IF AT1=1,+17
          IF V184>V180,+8   IF AT1=2,+9
          V181=V27          IF AT1=3,+2
          V182=V33          END
```

```
V183=V39            V104=V104+1
IF V1<801 AND V184  V61=V61+V15
=2,+12              V6=V6+V15
IF V181<1701,+11    V94=V94-V15
IF V183<1701,+7     LPG   NSWR    0   1   RAIL
IF V182<1701,+3     END
AT1=0               V103=V103+1
END                 V61=V61+V14
AT1=2               V5=V5+V14
V33=V33+V14         V94=V94-V14
+6                  V68=1
AT1=3               LPG   LMPR    0   1   RAIL
V39=V39+V15         END
+3                  V102=V102+1
AT1=1               V61=V61+V13
V27=V27+V13         V4=V4+V13
GET RAIL            V94=V94-V13
USE OPER1 D4        LPG   KKNR    0   1   RAIL
                    END
A   DUMMY17  IF VR1>V93,+2     A   EXIT    0   1   0
    +2
    V93=VR1
    IF VR1<V125,+2
    +2
    V125=VR1
    V130=V130+VR1
    V133=V130/V47
    V172=V111/V105
    V169=V125/V172
    IF VR1>0,+4
    V136=V136+1
    V142=V142+VR1
    END
    V137=V137+1
    V143=V143+VR1
    END
A   DUMMY18  IF VR2>V126,+2    A   EXIT    0   1   0
    +2
    V126=VR2
    IF VR2<V127,+2
    +2
    V127=VR2
    V131=V131+VR2
```

```
          V134=V131/V47
          V173=V112/V106
          V170=V127/V173
          IF VR2>0,+4
          V138=V138+1
          V144=V144+VR2
          END
          V139=V139+1
          V145=V145+VR2
          END
A    DUMMY19  IF VR3>V128,+2    A    EXIT     0   1   0
          +2
          V128=VR3
          IF VR3<V129,+2
          +2
          V129=VR3
          V132=V132+VR3
          V135=V132/V47
          V174=V113/V107
          V171=V129/V174
          IF VR3>0,+4
          V140=V140+1
          V146=V146+VR3
          END
          V141=V141+1
          V147=V147+VR3
          END
LPG   KKNR     GET RAIL         LPG   EXIT     0   1   0
          IF V67=0,WAIT
          V148=VR1+V13
          USE OPER4 D7
          FREE RAIL
          VR1=VR1+V13
          V40=VR1,TRACK
LPG   KKNT1    GET TRUCK1       LPG   EXIT     0   1   0
          IF V67=0,WAIT
          V149=VR1+V48
          USE OPER7 D8
          FREE TRUCK1
          VR1=VR1+V48
          V40=VR1
LPG   KKNT2    GET TRUCK2       LPG   EXIT     0   1   0
          IF V67=0,WAIT
```

```
        V150=VR1+V48
        USE OPER7 D8
        FREE TRUCK2
        VR1=VR1+V48
        V40=VR1
LPG  LMPR    GET RAIL       LPG  EXIT    0  1  0
        IF V122=0,WAIT
        V151=VR2+V14
        USE OPER5 D7
        FREE RAIL
        VR2=VR2+V14
        V41=VR2,TRACK
LPG  LMPT1   GET TRUCK1     LPG  EXIT    0  1  0
        IF V122=0,WAIT
        V152=VR2+V48
        USE OPER8 D8
        FREE TRUCK1
        VR2=VR2+V48
        V41=VR2
LPG  LMPT2   GET TRUCK2     LPG  EXIT    0  1  0
        IF V122=0,WAIT
        V153=VR2+V48
        USE OPER8 D8
        FREE TRUCK2
        VR2=VR2+V48
        V41=VR2
LPG  NSWR    GET RAIL       LPG  EXIT    0  1  0
        IF V124=0,WAIT
        V154=VR3+V15
        USE OPER6 D7
        FREE RAIL
        VR3=VR3+V15
        V42=VR3,TRACK
LPG  NSWT1   GET TRUCK1     LPG  EXIT    0  1  0
        IF V124=0,WAIT
        V155=VR3+V48
        USE OPER9 D8
        FREE TRUCK1
        VR3=VR3+V48
        V42=VR3
LPG  NSWT2   GET TRUCK2     LPG  EXIT    0  1  0
        IF V124=0,WAIT
        V156=VR3+V48
```

```
        USE OPER9 D8
        FREE TRUCK2
        VR3=VR3+V48
        V42=VR3
LPG  BRP    V166=V50-V46     LPG  EXIT    0  1  0
        V167=V166/V47
        V168=V167/24
        V94=V94+V168
LPG  LKB    V95=V95+13       LPG  EXIT    0  1  0
LPG  KKNS   IF V66=0,END     LPG  EXIT    0  1  0
        VR1=VR1-VR6
        V40=VR1
        VR15=VR15+VR6
        V89=VR15,TRACK
LPG  LMPS   IF V121=0,END    LPG  EXIT    0  1  0
        VR2=VR2-VR7
        V41=VR2
        VR22=VR22+VR7
        V90=VR22,TRACK
LPG  NSWS   IF V123=0,END    LPG  EXIT    0  1  0
        VR3=VR3-VR8
        V42=VR3
        VR23=VR23+VR8
        V91=VR23,TRACK
```

PART SCHEDULING

```
               Qty per  No. of   Start    Arrival
Part   Location    arrival  arrivals  (min)    frequency (min)
-----  --------    -------  --------  -----    ---------------
A      DUMMY1      1        1         0        0
A      DUMMY2      1        31        0        1440
A      DUMMY3      1        1         0        0
A      DUMMY4      1        1         0        0
A      DUMMY5      1        1         0        0
A      DUMMY6      1        1         0        0
A      DUMMY7      1        1         0        0
A      DUMMY8      1        1         0        0
A      DUMMY9      1        1         0        0
LPG    DUMMY10     1        31        0        1440
LPG    DUMMY11     1        31        0        1440
LPG    DUMMY12     1        31        0        1440
LPG    DUMMY13     1        31        0        1440
LPG    DUMMY14     1        31        0        1440
```

```
LPG    DUMMY15    1     31     0     1440
A      DUMMY17    1     31     0     1440
A      DUMMY18    1     31     0     1440
A      DUMMY19    1     31     0     1440
A      DUMMY20    1     1      0     0
A      DUMMY21    1     31     0     1440
LPG    BRP        1     744    0     60
LPG    LKB        1     744    0     60
LPG    KKNS       1     744    0     60
LPG    LMPS       1     744    0     60
LPG    NSWS       1     744    0     60
LPG    BRPRAIL    1     744    0     60

DOWNTIMES
              Freq(min,cyc)  Duration       Start or       Maintenance
Resource   Basis or Setup part  (min)         Lead part  Qty  resource
--------   ----- -------------  -------------  ---------  ---  --------
RAIL,*     CLOCK D9           D10          RAND      1    0
TRUCK1,*   CLOCK D11          D12          RAND      1    0
TRUCK2,*   CLOCK D11          D12          RAND      1    0

TRANSPORTER SPECIFICATIONS FOR RAIL
Speed     Pickup  Deposit  Start     Search    Accel    Decel
ft(m)/min  (sec)   (sec)   position  rule      (fpss)   (fpss)
---------  ------  -----   --------  --------  ------   ------
0          0       0       NQ5       OLDEST    0        0

PATH LOGIC FOR RAIL
                Speed       Distance ft(m)
From  To   Block  ft(m)/min    or Time(min)
----  --   -----  ---------    --------------
NQ5   19   0      0            300
NQ5   21   0      0            300
NQ5   25   0      0            300
19    20   0      0            300
38    39   0      0            200
39    NQ5  0      0            300
20    33   0      0            100
33    16   0      0            N 176,76.4
16    37   0      0            N 144,94.4
37    38   0      0            100
21    22   0      0            300
22    23   0      0            300
```

```
23   24   0    0        300
41   42   0    0        100
24   34   0    0        300
34   17   0    0        N 150,112
17   40   0    0        N 140,99.9
40   41   0    0        100
42   43   0    0        300
43   44   0    0        300
44   NQ5  0    0        300
25   36   0    0        200
36   18   0    0        N 163,85.9
18   45   0    0        N 146,65.4
45   46   0    0        300
46   NQ5  0    0        300

LOCATION INTERFACES FOR RAIL
Location Point  Location Point  Location Point  Location Point
-------- -----  -------- -----  -------- -----  -------- -----
BRPRAIL  NQ5    KKNR     16     LMPR     17     NSWR     18

SEARCH PRIORITY FOR RAIL
Type From    Search sequence...
---- ----    ------------------
PARK 16      NQ5
PARK 17      NQ5
PARK 18      NQ5

TRANSPORTER SPECIFICATIONS FOR TRUCK1
Speed      Pickup  Deposit  Start     Search    Accel   Decel
ft(m)/min  (sec)   (sec)    position  rule      (fpss)  (fpss)
---------  ------  -----    --------  --------  ------  ------
0          0       0        NQ1       OLDEST    0       0

PATH LOGIC FOR TRUCK1
                 Speed        Distance ft(m)
From  To   Block  ft(m)/min   or Time(min)
----  --   -----  ---------   --------------
NQ1   2    0      0           :01
NQ1   3    0      0           :01
NQ1   4    0      0           :01
2     26   0      0           300
26    27   0      0           200
27    10   0      0           100
```

10 47 0 0 100

47 48 0 0 200

48 58 0 0 300

58 NQ1 0 0 :01

3 28 0 0 300

28 29 0 0 300

29 35 0 0 200

35 11 0 0 N 168,18.5

11 49 0 0 N 168,18.5

49 50 0 0 200

50 51 0 0 300

51 59 0 0 300

59 NQ1 0 0 :01

4 30 0 0 300

30 12 0 0 120

12 52 0 0 120

52 60 0 0 300

60 NQ1 0 0 :01

LOCATION INTERFACES FOR TRUCK1

Location Point Location Point Location Point Location Point

-------- ----- -------- ----- -------- ----- -------- -----

BRPTK 2 BRPTL 3 BRPTN 4 KKNT1 10

LMPT1 11 NSWT1 12

SEARCH PRIORITY FOR TRUCK1

Type From Search sequence...

---- ---- ------------------

PARK 10 NQ1

PARK 11 NQ1

PARK 12 NQ1

TRANSPORTER SPECIFICATIONS FOR TRUCK2

Speed Pickup Deposit Start Search Accel Decel

ft(m)/min (sec) (sec) position rule (fpss) (fpss)

--------- ------ ----- -------- -------- ------ ------

0 0 0 NQ6 OLDEST 0 0

PATH LOGIC FOR TRUCK2

Speed Distance ft(m)

From To Block ft(m)/min or Time(min)

---- -- ----- --------- --------------

NQ6 7 0 0 :01

```
NQ6   8    0     0          :01
NQ6   9    0     0          :01
7    31    0     0          300
31    13    0     0          240
13    53    0     0          240
53    57    0     0          300
57    NQ6   0     0          :01
8    32    0     0          200
32    14    0     0          N 106,18
14    54    0     0          N 106,18
54    56    0     0          200
56    NQ6   0     0          :01
9    15    0     0          150
15    55    0     0          150
55    NQ6   0     0          :01

LOCATION INTERFACES FOR TRUCK2
Location Point  Location Point  Location Point  Location Point
-------- -----  -------- -----  -------- -----  -------- -----
KKNT2    13    LKBTK    7     LKBTL    8     LKBTN    9
LMPT2    14    NSWT2    15

SEARCH PRIORITY FOR TRUCK2
Type From     Search sequence...
---- ----     ------------------
PARK 13       NQ6
PARK 14       NQ6
PARK 15       NQ6

CAPACITIES
Resource Qty   Resource Qty   Resource Qty   Resource Qty   Resource Qty
-------- ----  -------- ----  -------- ----  -------- ----  -------- ----
BRP      2550  BRPRAIL  2000  BRPTK    2550  BRPTL    2550  BRPTN    2550
DUMMY1   50    DUMMY10  10    DUMMY11  10    DUMMY12  10    DUMMY13  10
DUMMY14  10    DUMMY15  10    DUMMY17  1     DUMMY18  1     DUMMY19  1
DUMMY2   100   DUMMY20  10    DUMMY21  10    DUMMY3   10    DUMMY4   10
DUMMY5   10    DUMMY6   10    DUMMY7   10    DUMMY8   10    DUMMY9   10
KKNR     4     KKNS     1     KKNT1    100   KKNT2    100   LKB      1500
LKBTK    1700  LKBTL    1700  LKBTN    1700  LMPR     4     LMPS     1
LMPT1    100   LMPT2    100   NSWR     4     NSWS     1     NSWT1    100
NSWT2    100   OPER1    &1    OPER2    &2    OPER3    &4    OPER4    &1
OPER5    &1    OPER6    &1    OPER7    2     OPER8    &3    OPER9    &2
RAIL     &5    16       10    17       10    18       10    TRUCK1   &100
```

```
2      100  3      100  4      100  10     100  11     100
12     100  TRUCK2 &30  7      50   8      50   9      50
13     50   14     50   15     50   19     10   20     10
21     10   22     10   23     10   24     10   25     10
26     100  27     100  28     100  29     100  30     100
31     50   32     50   35     100  33     10   34     10
36     10   37     10   38     10   39     10   40     10
41     10   42     10   43     10   44     10   45     10
46     10   47     100  48     100  49     100  50     100
51     100  52     100  53     50   54     50   55     50
56     50   57     50   58     100  59     100  60     100
NQ1    100  NQ5    10   NQ6    50

SIMULATION PARAMETERS                 GRAPHIC OPTIONS
Run   Startup Rept Resource           Graph Max Max Scr Fig Icon
(hrs) (hrs)  code to track  Seed      mode  row col clr clr file
----- ------ ---- --------  ----      ----- --- --- --- --- ----
744   0      4    0         168       4     100 200 D   W   PM.LIB

STATIC SYMBOLS
ID       Sym Clr Row Col  ID       Sym Clr Row Col  ID       Sym Clr Row Col
-------- --- --- --- ---  -------- --- --- --- ---  -------- --- --- --- ---
V40      0   0   23  96   V92      0   0   19  98   V61      0   0   51 110
V41      0   0   30  96   V42      0   0   37  96   V94      0   0   49 110
V95      0   0   32  48   V120     0   0   34  48   V96      0   0   23 107
V89      0   0   25  96   V90      0   0   32  96   V91      0   0   39  96
V97      0   0   30 107   V98      0   0   37 107   V99      0   0   25 107
V100     0   0   32 107   V101     0   0   39 107   V102     0   0   27 107
V103     0   0   34 107   V104     0   0   41 107   OPER2    8   C   51  87
OPER3    8   G   35  51   OPER1    8   4   44  91   OPER4    8   8   25  88
OPER7    8   W   25  84   OPER5    8   8   19  72   OPER8    8   W   19  68
OPER6    8   8   40  77   OPER9    8   W   40  73

DYNAMIC SYMBOLS
ID       Sym Clr  ID       Sym Clr  ID       Sym Clr  ID       Sym Clr
-------- --- ---  -------- --- ---  -------- --- ---  -------- --- ---
A         ,  R    LPG       .  7    RAIL     BW  8    TRUCK1   AW  W
TRUCK2   AW  2

TRANSPORTER POINTS
Point Row Col  Point Row Col  Point Row Col  Point Row Col  Point Row Col
----- --- ---  ----- --- ---  ----- --- ---  ----- --- ---  ----- --- ---
16    27  88   17    21  72   18    41  77   2     47  84   3     53  83
```

4 51 83 10 27 84 11 21 68 12 41 73 19 39 88
21 43 82 25 46 82 20 34 88 22 37 81 23 37 74
24 32 72 26 37 84 27 31 84 28 53 71 29 42 68
30 48 73 35 31 68 33 32 88 34 25 72 36 44 77
7 35 57 8 33 55 9 36 55 31 35 75 13 27 83
32 22 60 14 21 67 15 41 72 38 34 89 39 39 89
37 32 89 41 32 73 42 36 74 40 25 73 43 36 81
44 43 83 45 44 78 46 45 83 47 31 85 48 37 85
58 47 85 49 31 69 50 42 69 51 52 71 59 52 83
52 48 74 60 50 83 53 34 75 57 34 57 54 21 60
56 33 54 55 36 56 NQ1 51 84 NQ6 35 55 NQ5 44 88

TRANSPORTER PATH LAYOUT
From To Layout
---- ---- ------
NQ5 19 U5
NQ5 21 L6 U1
NQ5 25 D2 L6
19 20 U5
38 39 D5
39 NQ5 D5 L1
20 33 U2
33 16 U5
16 37 R1 D5
37 38 D2
21 22 U6 L1
22 23 L7
23 24 L2 U5
41 42 D4 R1
24 34 U7
34 17 U4
17 40 R1 D4
40 41 D7
42 43 R7
43 44 R2 D7
44 NQ5 R5 D1
25 36 L5 U2
36 18 U3
18 45 R1 D3
45 46 D1 R5
46 NQ5 R4 U1 R1
NQ1 2 U4
NQ1 3 R1 D2 L2

NQ1 4 L1

2 26 U10

26 27 U6

27 10 U4

10 47 R1 D4

47 48 D6

48 58 D10

58 NQ1 D4 L1

3 28 L12

28 29 L3 U11

29 35 U11

35 11 U10

11 49 R1 D10

49 50 D11

50 51 D10 R2

51 59 R12

59 NQ1 R1 U1

4 30 L10 U3

30 12 U7

12 52 R1 D7

52 60 D2 R9

60 NQ1 R1 D1

NQ6 7 R2

NQ6 8 U2

NQ6 9 D1

7 31 R18

31 13 R8 U8

13 53 L1 D7 L7

53 57 L18

57 NQ6 L2 D1

8 32 U11 R5

32 14 R7 U1

14 54 L7

54 56 L6 D12

56 NQ6 D2 R1

9 15 D6 R17 U1

15 55 L16 U5

55 NQ6 U1 L1

FIGURES AND LABELS

Type Clr Row Col Figure

---- --- --- --- ------

HORZ 0 11 51 LPG DISTRIBUTION SYSTEM

HORZ 0 16 68 LMP

HORZ 0 22 84 KKN

HORZ 0 38 72 NSW

HORZ 0 19 94 DAY

HORZ 0 23 98 STOCK

HORZ 0 30 98 STOCK

HORZ 0 37 98 STOCK

HORZ 0 21 94 KKN

HORZ 0 28 94 LMP

HORZ 0 35 94 NSW

HORZ 0 25 98 SALES

HORZ 0 32 98 SALES

HORZ 0 39 98 SALES

HORZ 0 23 109 TRUCK BRP

HORZ 0 30 109 TRUCK BRP

HORZ 0 37 109 TRUCK BRP

HORZ 0 25 109 TRUCK LKB

HORZ 0 32 109 TRUCK LKB

HORZ 0 39 109 TRUCK LKB

HORZ 0 27 109 RAIL

HORZ 0 34 109 RAIL

HORZ 0 41 109 RAIL

HORZ 0 30 29 GSP LKB

HORZ 0 32 35 STOCK

HORZ 0 34 29 SENT VOLUME

HORZ 0 47 106 BRP

HORZ 0 49 112 STOCK

HORZ 0 51 112 SENT VOLUME

HORZ 0 44 93 RAIL LOADING

HORZ 0 51 89 TRUCK LOADING

END

List of Integer Variable

V1 = actual KKN day1 stock @ 08:00 a.m.

V2 = actual LMP day1 stock @ 08:00 a.m.

V3 = actual NSW day1 stock @ 08:00 a.m.

V4 = intransit volume that will arrive KKN on day1

V5 = intransit volume that will arrive LMP on day1

V6 = intransit volume that will arrive NSW on day1

V7 = estimated KKN day1 sales

V8 = estimated LMP day1 sales

V9 = estimated NSW day1 sales

V10 = estimated KKN day2 sales

V11 = estimated LMP day2 sales

V12 = estimated NSW day2 sales

V13 = rail capacity to KKN

V14 = rail capacity to LMP

V15 = rail capacity to NSW

V16 = number of truck sent to KKN in each day = V72 + V75

V17 = number of truck sent to LMP in each day = V73 + V76

V18 = number of truck sent to NSW in each day = V74 + V77

V19 = volume sent by truck from GSP LKB to KKN in each day = V75 × V48

V20 = volume sent by truck from GSP LKB to LMP in each day = V76× V48

V21 = volume sent by truck from GSP LKB to NSW in each day = V77 × V48

V22 = dummy = V1 – V7

V23 = dummy = V22 + V4

V24 = estimated KKN day2 stock @ 08:00 a.m. = V23+V19

V25 = dummy = V24 - V10

V26 = dummy = V25 + V13

V27 = estimated KKN day3 stock @ 08:00 a.m. = V26+V114

V28 = dummy = V2 – V8

V29 = dummy = V28 + V5

V30 = estimated LMP day2 stock @ 08:00 a.m. = V29+V20

V31 = dummy = V30 - V11

V32 = dummy = V31+ V14

V33 = estimated LMP day3 stock @ 08:00 a.m. = V32+V115

V34 = dummy = V3 – V9

V35= dummy = V34 + V6

V36 = estimated NSW day2 stock @ 08:00 a.m. = V35+V116

V37 = dummy = V36 - V12

V38 = dummy = V37+ V15

V39 = estimated NSW day3 stock @ 08:00 a.m. = V38+V116

V40 = KKN stock @ any real time

V41 = LMP stock @ any real time

V42 = NSW stock @ any real time

V43 = KKN monthly demand

V44 = LMP monthly demand

V45 = NSW monthly demand

V46 = LKB monthly committed volume

V47 = number of days in month

V48 = truck capacity

V49 = dummy = V43+V45

V50 = total monthly demand = V49 + V44

V51 = dummy = to find whether or not to load @ BRP

V52 = dummy = V43 – V87

V53 = dummy = V87 – V43

V54 = dummy = V45 – V53

V55 = dummy = V44 – V46

V56 = dummy = V87 – V49

V57 = dummy = V55 – V56

V58 = dummy = day n used in finding day1 sales and day2 sales

V59 = dummy = destination of rail#1

V60 = dummy = destination of rail#2

V61 = total cumulative volume sent from BRP

V62 = dummy = VR16 + VR17

V63 = dummy = V62 + VR18

V64 = dummy = VR19 + VR20

V65 = dummy = V64 + VR21

V66 = dummy = to find whether or not to sell @ KKN

V67 = dummy = to find whether or not to unload @ KKN

V68 = dummy = indicator shows that rail is sent to LMP

V69 = dummy = indicator shows how many days rail is sent to LMP

V70 = dummy = whether or not 2 rails can be sent to NSW = V39 +V15

V71 = dummy = whether or not 2 rails can be sent to KKN = V27 +V13

V72 = number of trucks sent from BRP to KKN per day

V73 = number of trucks sent from BRP to LMP per day

V74 = number of trucks sent from BRP to NSW per day

V75 = number of trucks sent from GSP LKB to KKN per day

V76 = number of trucks sent from GSP LKB to LMP per day

V77 = number of trucks sent from GSP LKB to NSW per day

V78 = number of rails sent form BRP in each day

V79 = dummy = indicator showing whether it is rail#1 or rail #2

V80 = dummy = VR16/V48

V81 = dummy = VR17/V48

V82 = dummy = VR18/V48

V83 = dummy = VR19/V48

V84 = dummy = VR20/V48

V85 = dummy = VR21/V48

V86 = number of selling days in a month

V87 = maximum volume that can be transported by rail per month

V88 = dummy = V87 + 1

V89 = KKN cumulative sales by hour

V90 = LMP cumulative sales by hour

V91 = NSW cumulative sales by hour

V92 = day n

V93 = KKN maximum stock

V94 = BRP stock @ any real time

V95 = GSP LKB stock @ any real time

V96 = cumulative number of truck sent from BRP to KKN

V97 = cumulative number of truck sent from BRP to LMP

V98 = cumulative number of truck sent from BRP to NSW

V99 = cumulative number of truck sent from GSP LKB to KKN

V100 = cumulative number of truck sent from GSP LKB to LMP

V101 = cumulative number of truck sent from GSP LKB to NSW

V102 = cumulative number of rail sent from BRP to KKN

V103 = cumulative number of rail sent from BRP to LMP

V104 = cumulative number of rail sent from BRP to NSW

V105 = KKN selling hour per day

V106 = LMP selling hour per day

V107 = NSW selling hour per day

V108 = KKN day1 actual sales

V109 = LMP day1 actual sales

V110 = NSW day1 actual sales

V111 = daily demand from plan of KKN

V112 = daily demand from plan of LMP

V113 = daily demand from plan of NSW

V114 = total volume sent by truck to KKN = V16 $\times$ V48

V115 = total volume sent by truck to LMP = V17 $\times$ V48

V116 = total volume sent by truck to NSW = V18 $\times$ V48

V117 = KKN cumulative sales by day

V118 = LMP cumulative sales by day

V119 = NSW cumulative sales by day

V120 = total cumulative volume sent from GSP LKB

V121 = dummy = to find whether or not to sell @ LMP

V122 = dummy = to find whether or not to unload @ LMP

V123 = dummy = to find whether or not to sell @ NSW

V124 = dummy = to find whether or not to unload @ NSW

V125 = KKN minimum stock

V126 = LMP maximum stock

V127 = LMP minimum stock

V128 = NSW maximum stock

V129 = NSW minimum stock

V130 = dummy = V142 + V143

V131 = dummy = V144 + V145

V132 = dummy = V146 + V147

V133 = KKN average opening stock

V134 = LMP average opening stock

V135 = NSW average opening stock

V136 = dummy = counter of number of shortage days at KKN

V137 = dummy = counter of number of normal days at KKN

V138 = dummy = counter of number of shortage days at LMP

V139 = dummy = counter of number of normal days at LMP

V140 = dummy = counter of number of shortage days at NSW

V141 = dummy = counter of number of normal days at NSW

V142 = dummy = total shortage volume at KKN

V143 = dummy = cumulative opening stock at KKN

V144 = dummy = total shortage volume at LMP

V145 = dummy = cumulative opening stock at LMP

V146 = dummy = total shortage volume at NSW

V147 = dummy = cumulative opening stock at NSW

V148 = dummy = indicator before unloading at KKN

V149 = dummy = indicator before unloading at KKN

V150 = dummy = indicator before unloading at KKN

V151 = dummy = indicator before unloading at LMP

V152 = dummy = indicator before unloading at LMP

V153 = dummy = indicator before unloading at LMP

V154 = dummy = indicator before unloading at NSW

V155 = dummy = indicator before unloading at NSW

V156 = dummy = indicator before unloading at NSW

V157 = dummy = trigger point to increase the number of truck to LMP

V158 = dummy = trigger point to increase the number of truck to NSW

V159 = dummy = V157 - V2

V160 = dummy = V159 / V165

V161 = increased number of truck sent to LMP = V160 / V48

V162 = dummy = V158 – V3

V163 = dummy = V160 / V165

V164 = increased number of truck sent to NSW = V163 / V48

V165 = days to cover shortage

V166 = monthly volume that should be sent from BRP = V50 – V46

V167 = daily volume that should be received from GSP Rayong = V166 / V47

V168 = volume that should be received from GSP Rayong in each hour = V167 / 24

V169 = longest shortage hours at KKN = V125 / V172

V170 = longest shortage hours at LMP = V127 / V173

V171 = longest shortage hours at NSW = V129 / V174

V172 = KKN hourly sales = V111 / V105

V173 = KKN hourly sales = V112 / V106

V174 = KKN hourly sales = V113 / V107

V175 = number of rail in the system

V176 = dummy to test the added number of rail

V177= variation in number of rail in each day

V178 = number of available rail if added = V176 + V177

V179 = dummy to check whether it is odd or even

V180 = number of available rail in each day

V181 = dummy to check ullage at KKN = V27 + V13

V182 = dummy to check ullage at LMP = V33 + V14

V183 = dummy to check ullage at NSW = V33 + V15

V184= counter to check the number of rail sent in each day

List of Real Variable

VR1 = V40

VR2 = V41

VR3 = V42

VR4 = dummy to test the added number of rail

VR6 = V108/V105

VR7 = V109/V106

VR8 = V110/V107

VR9 = VR16/V48

VR10= VR17/V48

VR11 = VR18/V48

VR12 = VR19/V48

VR13 = VR20/V48

VR14 = VR21/V48

VR15 = KKN cumulative sales by hour

VR16 = truck volume sent from BRP to KKN per day

VR17 = truck volume sent from BRP to LMP per day

VR18 = truck volume sent from BRP to NSW per day

VR19 = truck volume sent from GSP LKB to KKN per day

VR20 = truck volume sent from GSP LKB to LMP per day

VR21 = truck volume sent from GSP LKB to NSW per day

VR22 = LMP cumulative sales by hour

VR23 = NSW cumulative sales by hour

List of Attribute

AT1 = attribute to indicate the destination depot

Appendix K

Result of the Base Line Simulation Model

ProModel Results for MAR2000

*LPG DISTRIBUTION SYSTEM

Date: 7/18/2000 Time: 16:54:42

Simulation Time: 744.00 hours

RESOURCE UTILIZATION SUMMARY

				Avg.	Avg.	Max	Final		Total
	Capa-	%	Total	min/	con-	con-	con-	Times	hrs
Resource	city	Util	entry	entry	tents	tents	tents	down	down
--------	----	----	-----	-----	-----	-----	-----	----	----
DUMMY1	50	0.00	1	0.00	0.0	1	0	0	0.0
DUMMY2	100	0.00	31	0.02	0.0	1	0	0	0.0
DUMMY3	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY4	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY5	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY6	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY7	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY8	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY9	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY10	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTK	2550	0.00	0	0.00	0.0	0	0	0	0.0
TRUCK1	19	29.83	170	1488.21	5.7	0.02*	0.87**	34	893.5
OPER2	2	8.41	170	44.19	0.2	2	0	0	0.0
DUMMY11	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTL	2550	0.01	164	87.10	0.3	8	0	0	0.0
DUMMY12	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTN	2550	0.00	6	393.87	0.1	5	0	0	0.0
DUMMY13	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTK	1700	0.00	0	0.00	0.0	0	0	0	0.0
TRUCK2	23	32.78	589	571.36	7.5	0.00*	0.01**	37	589.3
OPER3	4	17.89	589	54.23	0.7	4	0	0	0.0
DUMMY14	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTL	1700	0.12	589	156.64	2.1	19	0	0	0.0
DUMMY15	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTN	1700	0.00	0	0.00	0.0	0	0	0	0.0
DUMMY16	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPRAIL	4	14.30	58	440.28	0.6	2	0	0	0.0
RAIL	4	63.83	58	1964.99	2.6	0.00*	0.01**	0	0.0
OPER1	1	38.94	58	299.70	0.4	1	0	0	0.0
DUMMY17	1	0.00	31	0.00	0.0	1	0	0	0.0
DUMMY18	1	0.00	31	0.00	0.0	1	0	0	0.0
DUMMY19	1	0.00	31	0.00	0.0	1	0	0	0.0
KKNR	4	14.66	35	747.77	0.6	2	1	0	0.0

OPER4	1	36.73	34	482.25	0.4	1	0	0	0.0
KKNT1	100	0.00	0	0.00	0.0	0	0	0	0.0
OPER7	2	0.00	0	0.00	0.0	0	0	0	0.0
KKNT2	100	0.00	0	0.00	0.0	0	0	0	0.0
LMPR	4	0.54	2	481.54	0.0	1	0	0	0.0
OPER5	1	2.16	2	481.54	0.0	1	0	0	0.0
LMPT1	100	1.72	164	467.71	1.7	8	5	0	0.0
OPER8	3	33.18	748	59.41	1.0	3	0	0	0.0
LMPT2	100	1.44	589	109.11	1.4	10	0	0	0.0
NSWR	4	8.63	21	734.08	0.3	2	0	0	0.0
OPER6	1	23.32	21	495.77	0.2	1	0	0	0.0
NSWT1	100	0.01	6	62.38	0.0	3	0	0	0.0
OPER9	2	0.40	6	59.02	0.0	2	0	0	0.0
NSWT2	100	0.00	0	0.00	0.0	0	0	0	0.0
BRP	2550	0.00	744	0.00	0.0	1	0	0	0.0
LKB	1500	0.00	744	0.00	0.0	1	0	0	0.0
KKNS	1	0.00	744	0.00	0.0	1	0	0	0.0
LMPS	1	0.00	744	0.00	0.0	1	0	0	0.0
NSWS	1	0.00	744	0.00	0.0	1	0	0	0.0
EXIT	1	0.00	4656	0.00	0.0	1	0	0	0.0

* Percentage of time traveling to and picking up parts.

** Average minutes to travel to and pick up each part.

VARIANCE SUMMARY

Resource	Avg. Contents	Std. dev.	Avg. min/ exit	Std. dev. (min)	Min time (min)	Max time (min)	Zero time count	Total Count
TRUCK1	5.67	9.41	433.67	1134.51	55.02	7722.52	0	165
OPER2	0.17	0.75	44.19	2.54	40.02	48.82	0	170
TRUCK2	7.54	17.16	571.36	109.23	377.51	781.91	0	589
OPER3	0.72	3.19	54.23	2.34	45.74	60.90	0	589
RAIL	2.55	3.74	1241.57	2215.74	125.19	13469.38	0	57
OPER1	0.39	0.49	299.70	19.07	270.96	333.63	0	58
OPER4	0.37	0.48	482.25	33.66	382.17	557.13	0	34
OPER5	0.02	0.15	481.54	20.46	467.07	496.00	0	2
OPER8	1.00	2.68	59.41	2.50	55.02	63.99	0	748
OPER6	0.23	0.42	495.77	43.28	419.45	582.27	0	21
OPER9	0.01	0.13	59.02	2.80	55.14	61.92	0	6

USER VARIABLES WITH VALUES OTHER THAN ZERO

V1=1008 V2=1541 V3=1499 V4=458 V5=80

V7=600 V8=467 V9=393 V10=600 V11=467

V12=393 V13=458 V14=458 V15=510 V17=24

V20=304 V22=408 V23=866 V24=866 V25=266

V26=724 V27=724 V28=1074 V29=1154 V30=1458

V31=991 V32=1449 V33=1833 V34=1106 V35=1616

V36=1616 V37=1223 V38=1733 V39=1733 V40=880

V41=1418 V42=1603 V43=16200 V44=12600 V45=10600

V46=9100 V47=31 V48=16 V49=26800 V50=39400

V53=11800 V55=3500 V56=1200 V57=2300 V58=3

V59=1 V61=30376 V62=74 V63=74 V64=293

V65=293 V70=1082 V71=1182 V73=5 V76=19

V78=1 V79=1 V81=4 V84=18 V86=27

V87=28000 V88=28001 V89=16191 V90=12566 V91=10701

V92=31 V93=1548 V94=1384 V95=1048 V97=164

V98=6 V100=602 V102=35 V103=2 V104=21

V105=10 V106=10 V107=10 V108=586 V109=507

V110=406 V111=600 V112=467 V113=393 V115=384

V117=16192 V118=12566 V119=10702 V120=9424 V125=370

V126=1739 V127=491 V128=1639 V129=59 V130=33431

V131=34897 V132=37498 V133=1078 V134=1125 V135=1209

V137=31 V139=31 V141=31 V143=33431 V145=34897

V147=37498 V148=1466 V151=1697 V152=1557 V153=1306

V154=2009 V155=1079 V157=801 V158=601 V159=236

V160=39 V162=542 V163=90 V165=6 V166=30300

V167=977 V168=40 V169=6 V170=10 V171=1

V172=60 V173=46 V174=39

ProModel Results for MAR2000

*LPG DISTRIBUTION SYSTEM

Date: 7/18/2000 Time: 16:55:39

Simulation Time: 744.00 hours

RESOURCE UTILIZATION SUMMARY

Resource	Capa-city	% Util	Total entry	Avg. min/ entry	Avg. con-tents	Max con-tents	Final con-tents	Total Times down	hrs down
DUMMY1	50	0.00	1	0.00	0.0	1	0	0	0.0
DUMMY2	100	0.00	31	0.02	0.0	1	0	0	0.0
DUMMY3	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY4	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY5	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY6	10	10.00	1	44640.00	1.0	1	1	0	0.0

DUMMY7	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY8	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY9	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY10	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTK	2550	0.00	0	0.00	0.0	0	0	0	0.0
TRUCK1	19	28.34	158	1521.08	5.4	0.00*	0.01**	36	765.2
OPER2	2	7.91	158	44.69	0.2	2	0	0	0.0
DUMMY11	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTL	2550	0.01	158	81.14	0.3	6	0	0	0.0
DUMMY12	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTN	2550	0.00	0	0.00	0.0	0	0	0	0.0
DUMMY13	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTK	1700	0.00	0	0.00	0.0	0	0	0	0.0
TRUCK2	23	32.95	589	574.31	7.6	0.00*	0.01**	15	655.9
OPER3	4	17.91	589	54.31	0.7	4	0	0	0.0
DUMMY14	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTL	1700	0.12	589	156.88	2.1	19	0	0	0.0
DUMMY15	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTN	1700	0.00	0	0.00	0.0	0	0	0	0.0
DUMMY16	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPRAIL	4	14.49	58	446.06	0.6	2	0	0	0.0
RAIL	4	63.21	58	1946.11	2.5	0.00*	0.01**	1	16.3
OPER1	1	39.37	58	302.98	0.4	1	0	0	0.0
DUMMY17	1	0.00	31	0.00	0.0	1	0	0	0.0
DUMMY18	1	0.00	31	0.00	0.0	1	0	0	0.0
DUMMY19	1	0.00	31	0.00	0.0	1	0	0	0.0
KKNR	4	14.92	35	760.94	0.6	2	1	0	0.0
OPER4	1	36.91	34	484.64	0.4	1	0	0	0.0
KKNT1	100	0.00	0	0.00	0.0	0	0	0	0.0
OPER7	2	0.00	0	0.00	0.0	0	0	0	0.0
KKNT2	100	0.00	0	0.00	0.0	0	0	0	0.0
LMPR	4	0.56	2	502.96	0.0	1	0	0	0.0
OPER5	1	2.25	2	502.96	0.0	1	0	0	0.0
LMPT1	100	1.67	158	471.16	1.7	6	5	0	0.0
OPER8	3	33.05	742	59.66	1.0	3	0	0	0.0
LMPT2	100	1.47	589	111.23	1.5	10	0	0	0.0
NSWR	4	7.59	21	644.98	0.3	1	1	0	0.0
OPER6	1	21.64	20	482.92	0.2	1	0	0	0.0
NSWT1	100	0.00	0	0.00	0.0	0	0	0	0.0
OPER9	2	0.00	0	0.00	0.0	0	0	0	0.0
NSWT2	100	0.00	0	0.00	0.0	0	0	0	0.0
BRP	2550	0.00	744	0.00	0.0	1	0	0	0.0
LKB	1500	0.00	744	0.00	0.0	1	0	0	0.0

KKNS	1	0.00	744	0.00	0.0	1	0	0	0.0
LMPS	1	0.00	744	0.00	0.0	1	0	0	0.0
NSWS	1	0.00	744	0.00	0.0	1	0	0	0.0
EXIT	1	0.00	4643	0.00	0.0	1	0	0	0.0

* Percentage of time traveling to and picking up parts.

** Average minutes to travel to and pick up each part.

VARIANCE SUMMARY

Resource	Avg. Con- tents	Std. dev.	Avg. min/ exit	Std. dev.	Min time (min)	Max time (min)	Zero time count	Total Count
TRUCK1	5.38	7.22	516.67	2271.35	55.01	20278.39	0	153
OPER2	0.16	0.73	44.69	2.57	40.10	48.98	0	158
TRUCK2	7.58	17.48	574.31	110.05	373.35	788.71	0	589
OPER3	0.72	3.20	54.31	2.54	45.67	61.06	0	589
RAIL	2.53	3.75	1501.33	2939.26	215.40	17199.11	0	56
OPER1	0.39	0.49	302.98	18.32	271.58	335.32	0	58
OPER4	0.37	0.48	484.64	32.53	400.10	549.84	0	34
OPER5	0.02	0.15	502.96	4.40	499.85	506.07	0	2
OPER8	0.99	2.66	59.66	2.48	55.02	64.00	0	742
OPER6	0.22	0.41	482.92	27.14	436.05	526.03	0	20
OPER9	0.00	0.00	0.00	0.00	0.00	0.00	0	0

USER VARIABLES WITH VALUES OTHER THAN ZERO

V1=1329 V2=1642 V3=1314 V4=458 V5=80

V6=510 V7=600 V8=467 V9=393 V10=600

V11=467 V12=393 V13=458 V14=458 V15=510

V17=24 V20=304 V22=729 V23=1187 V24=1187

V25=587 V26=1045 V27=1045 V28=1175 V29=1255

V30=1559 V31=1092 V32=1550 V33=1934 V34=921

V35=1431 V36=1431 V37=1038 V38=1548 V39=1548

V40=1183 V41=1530 V42=1454 V43=16200 V44=12600

V45=10600 V46=9100 V47=31 V48=16 V49=26800

V50=39400 V53=11800 V55=3500 V56=1200 V57=2300

V58=3 V59=1 V60=3 V61=30184 V62=74

V63=74 V64=293 V65=293 V70=2148 V71=1503

V73=5 V76=19 V78=2 V79=2 V81=4

V84=18 V86=27 V87=28000 V88=28001 V89=15888

V90=12358 V91=10245 V92=31 V93=1805 V94=1576

V95=1048 V97=158 V100=589 V102=35 V103=2

V104=21 V105=10 V106=10 V107=10 V108=604

V109=496 V110=370 V111=600 V112=467 V113=393

V115=384 V117=15889 V118=12358 V119=10245 V120=9424

V125=515 V126=1767 V127=631 V128=1759 V129=525

V130=37366 V131=37507 V132=38878 V133=1205 V134=1209

V135=1254 V137=31 V139=31 V141=31 V143=37366

V145=37507 V147=38878 V148=1787 V151=1583 V152=1658

V153=1386 V154=1824 V157=801 V158=601 V159=170

V160=28 V162=76 V163=12 V165=6 V166=30300

V167=977 V168=40 V169=8 V170=13 V171=13

V172=60 V173=46 V174=39

ProModel Results for MAR2000

*LPG DISTRIBUTION SYSTEM

Date: 7/18/2000 Time: 16:56:46

Simulation Time: 744.00 hours

RESOURCE UTILIZATION SUMMARY

Resource	Capa- city	% Util	Total entry	Avg. min/ entry	Avg. con- tents	Max con- tents	Final con- tents	Times down	Total hrs down
DUMMY1	50	0.00	1	0.00	0.0	1	0	0	0.0
DUMMY2	100	0.00	31	0.02	0.0	1	0	0	0.0
DUMMY3	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY4	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY5	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY6	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY7	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY8	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY9	10	10.00	1	44640.00	1.0	1	1	0	0.0
DUMMY10	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTK	2550	0.00	0	0.00	0.0	0	0	0	0.0
TRUCK1	19	28.52	161	1502.60	5.4	0.00*	0.01**	37	643.2
OPER2	2	8.05	161	44.64	0.2	2	0	0	0.0
DUMMY11	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTL	2550	0.01	158	83.99	0.3	7	0	0	0.0
DUMMY12	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPTN	2550	0.00	3	61.06	0.0	3	0	0	0.0
DUMMY13	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTK	1700	0.00	0	0.00	0.0	0	0	0	0.0
TRUCK2	23	32.75	589	570.80	7.5	0.00*	0.01**	26	562.0
OPER3	4	17.89	589	54.24	0.7	4	0	0	0.0
DUMMY14	10	0.00	31	0.00	0.0	1	0	0	0.0

LKBTL	1700	0.12	589	156.49	2.1	19	0	0	0.0
DUMMY15	10	0.00	31	0.00	0.0	1	0	0	0.0
LKBTN	1700	0.00	0	0.00	0.0	0	0	0	0.0
DUMMY16	10	0.00	31	0.00	0.0	1	0	0	0.0
BRPRAIL	4	14.64	58	450.74	0.6	2	0	0	0.0
RAIL	4	63.89	58	1966.79	2.6	0.00*	0.01**	2	21.3
OPER1	1	39.88	58	306.95	0.4	1	0	0	0.0
DUMMY17	1	0.00	31	0.00	0.0	1	0	0	0.0
DUMMY18	1	0.00	31	0.00	0.0	1	0	0	0.0
DUMMY19	1	0.00	31	0.00	0.0	1	0	0	0.0
KKNR	4	15.55	36	771.15	0.6	2	1	0	0.0
OPER4	1	37.88	35	483.13	0.4	1	0	0	0.0
KKNT1	100	0.00	0	0.00	0.0	0	0	0	0.0
OPER7	2	0.00	0	0.00	0.0	0	0	0	0.0
KKNT2	100	0.00	0	0.00	0.0	0	0	0	0.0
LMPR	4	0.55	2	487.06	0.0	1	0	0	0.0
OPER5	1	2.18	2	487.06	0.0	1	0	0	0.0
LMPT1	100	1.65	158	467.15	1.7	7	5	0	0.0
OPER8	3	32.96	742	59.49	1.0	3	0	0	0.0
LMPT2	100	1.44	589	108.83	1.4	10	0	0	0.0
NSWR	4	8.07	20	720.76	0.3	2	1	0	0.0
OPER6	1	21.16	19	497.15	0.2	1	0	0	0.0
NSWT1	100	0.00	3	60.61	0.0	3	0	0	0.0
OPER9	2	0.20	3	58.28	0.0	2	0	0	0.0
NSWT2	100	0.00	0	0.00	0.0	0	0	0	0.0
BRP	2550	0.00	744	0.00	0.0	1	0	0	0.0
LKB	1500	0.00	744	0.00	0.0	1	0	0	0.0
KKNS	1	0.00	744	0.00	0.0	1	0	0	0.0
LMPS	1	0.00	744	0.00	0.0	1	0	0	0.0
NSWS	1	0.00	744	0.00	0.0	1	0	0	0.0
EXIT	1	0.00	4646	0.00	0.0	1	0	0	0.0

* Percentage of time traveling to and picking up parts.

** Average minutes to travel to and pick up each part.

VARIANCE SUMMARY

	Avg.		Avg.	Std.	Min	Max	Zero	
	Con-	Std.	min/	dev.	time	time	time	Total
Resource	tents	dev.	exit	(min)	(min)	(min)	count	Count
--------	-----	----	----	-----	-----	-----	-----	-----
TRUCK1	5.42	8.06	341.52	1128.81	55.04	8817.31	0	156
OPER2	0.16	0.73	44.64	2.54	40.04	48.99	0	161
TRUCK2	7.53	17.05	570.80	109.82	366.38	784.55	0	589

OPER3	0.72	3.19	54.24	2.32	47.04	60.57	0	589
RAIL	2.56	3.72	1214.18	2192.33	186.51	10648.90	0	56
OPER1	0.40	0.49	306.95	18.00	270.11	335.90	0	58
OPER4	0.38	0.49	483.13	35.53	427.52	576.79	0	35
OPER5	0.02	0.15	487.07	33.34	463.49	510.64	0	2
OPER8	0.99	2.66	59.49	2.54	55.02	63.99	0	742
OPER6	0.21	0.41	497.15	26.01	450.65	552.28	0	19
OPER9	0.00	0.11	58.28	2.59	55.88	61.02	0	3

USER VARIABLES WITH VALUES OTHER THAN ZERO

V1=1291 V2=1460 V3=961 V4=458 V5=80
V6=510 V7=600 V8=467 V9=393 V10=600
V11=467 V12=393 V13=458 V14=458 V15=510
V17=24 V20=304 V22=691 V23=1149 V24=1149
V25=549 V26=1007 V27=1007 V28=993 V29=1073
V30=1377 V31=910 V32=1368 V33=1752 V34=568
V35=1078 V36=1078 V37=685 V38=1195 V39=1195
V40=1109 V41=1403 V42=1123 V43=16200 V44=12600
V45=10600 V46=9100 V47=31 V48=16 V49=26800
V50=39400 V53=11800 V55=3500 V56=1200 V57=2300
V58=3 V59=1 V60=3 V61=30180 V62=74
V63=74 V64=293 V65=293 V70=1373 V71=1465
V73=5 V76=19 V78=2 V79=2 V81=4
V84=18 V86=27 V87=28000 V88=28001 V89=16420
V90=12485 V91=10115 V92=31 V93=1555 V94=1580
V95=1048 V97=158 V98=3 V100=576 V102=36
V103=2 V104=20 V105=10 V106=10 V107=10
V108=640 V109=441 V110=348 V111=600 V112=467
V113=393 V115=384 V117=16421 V118=12485 V119=10115
V120=9424 V125=466 V126=1638 V127=520 V128=1657
V129=306 V130=34031 V131=33026 V132=37886 V133=1097
V134=1065 V135=1222 V137=31 V139=31 V141=31
V143=34031 V145=33026 V147=37886 V148=1749 V151=1238
V152=1476 V153=1275 V154=1471 V155=832 V157=801
V158=601 V159=11 V160=1 V162=295 V163=49
V165=6 V166=30300 V167=977 V168=40 V169=7
V170=11 V171=7 V172=60 V173=46 V174=39

Appendix L

Transportation Trips as a Result of the Simulation Model

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		23	23	23	22	23	23	23	23	22	24	24	23	23
Truck in BRP Fleet (trucks)		26	13	17	28	18	24	40	34	37	27	36	49	29
Rail (rails)		4	4	4	4	4	4	4	4	4	4	4	4	4
Total truck required (trucks)		49	36	40	50	41	47	63	57	59	51	60	72	52
	Truck from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Truck from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
(trips)	Rail from BRP	38	35	35	39	38	37	43	42	42	39	41	43	39
	Total truck trips	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from GSP LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
LMP	Truck from BRP	312	220	190	246	218	225	347	374	305	311	362	392	292
(trips)	Rail from BRP	1	1	2	0	1	2	1	1	0	1	1	1	1
	Total truck trips	901	752	779	816	807	795	936	963	875	900	932	981	870
	Truck from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
NSW	Truck from BRP	32	9	0	10	0	3	115	128	137	63	134	203	70
(trips)	Rail from BRP	20	19	20	20	20	19	18	18	18	19	18	17	19
	Total truck trips	32	9	0	10	0	3	115	128	137	63	134	203	70
	Truck from GSP LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
Total	Truck from BRP	344	229	190	256	218	228	462	502	442	374	496	595	361
(trips)	Rail from BRP	59	55	57	59	59	58	62	61	60	59	60	61	59
	Total truck trips	933	761	779	826	807	798	1,051	1,091	1,012	963	1,066	1,184	939

Table L-1: Transportation Trips as a Result of the Simulation model as of 2001-2005

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		23	23	23	24	23	24	22	22	24	22	22	24	23
Truck in BRP Fleet (trucks)		36	34	31	30	29	36	43	43	52	38	43	51	39
Rail (rails)		4	4	4	4	4	4	4	4	4	4	4	4	4
Total truck required (trucks)		59	57	54	54	52	60	65	65	76	60	65	75	62
KKN	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rail from BRP	42	38	40	40	40	41	42	44	44	40	42	46	42
	Total truck	0	0	0	0	0	0	0	0	0	0	0	0	0
LMP	Truck from LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
	Truck from BRP	374	342	350	334	313	341	412	438	411	376	451	481	385
	Rail from BRP	1	1	1	1	1	1	1	1	0	1	1	1	1
	Total truck	963	874	939	904	902	911	1,001	1,027	981	965	1,021	1,070	963
NSW	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	164	65	35	39	64	81	189	219	241	158	215	290	147
	Rail from BRP	17	17	20	19	19	18	16	16	16	17	16	15	17
	Total truck	164	65	35	39	64	81	189	219	241	158	215	290	147
Total	Truck from LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
	Truck from BRP	538	407	385	373	377	422	601	657	652	534	666	771	532
	Rail from BRP	60	56	61	60	60	60	59	61	60	58	59	62	60
	Total truck	1,127	939	974	943	966	992	1,190	1,246	1,222	1,123	1,236	1,360	1,110

Table L-1: Transportation Trips as a Result of the Simulation model as of 2001-2005 (Cont.)

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		23	24	23	22	24	24	24	24	24	23	24	23	24
Truck in BRP Fleet (trucks)		48	45	43	39	36	47	49	57	49	45	61	52	48
Rail (rails)		4	4	4	4	4	4	4	4	4	4	4	4	4
Total truck required (trucks)		71	69	66	61	60	71	73	81	73	68	85	75	71
KKN	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rail from BRP	42	41	43	42	42	43	46	48	45	44	45	45	44
	Total truck	0	0	0	0	0	0	0	0	0	0	0	0	0
LMP	Truck from LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
	Truck from BRP	472	408	412	391	375	411	473	531	455	438	529	531	452
	Rail from BRP	1	0	0	0	1	1	1	1	1	0	1	1	1
	Total truck	1,061	940	1,001	961	964	981	1,062	1,120	1,025	1,027	1,099	1,120	1,030
NSW	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	253	164	144	127	161	173	291	354	314	259	321	375	245
	Rail from BRP	16	15	18	17	16	16	14	13	14	16	14	13	15
	Total truck	253	164	144	127	161	173	291	354	314	259	321	375	245
Total	Truck from LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
	Truck from BRP	725	572	556	518	536	584	764	885	769	697	850	906	697
	Rail from BRP	59	56	61	59	59	60	61	62	60	60	60	59	60
	Total truck	1,314	1,104	1,145	1,088	1,125	1,154	1,353	1,474	1,339	1,286	1,420	1,495	1,275

Table L-1: Transportation Trips as a Result of the Simulation model as of 2001-2005 (Cont.)

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		23	21	18	20	20	22	19	15	19	19	21	16	19
Truck in BRP Fleet (trucks)		9	7	2	3	3	7	5	4	5	6	9	5	5
Rail (rails)		7	7	7	7	7	7	7	7	7	7	7	7	7
Total truck required (trucks)		32	28	20	23	23	29	24	19	24	25	30	21	25
KKN	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rail from BRP	46	42	44	45	49	46	50	52	48	47	48	50	47
	Total truck	0	0	0	0	0	0	0	0	0	0	0	0	0
LMP	Truck from LKB	589	551	589	570	589	570	589	589	570	589	570	589	580
	Truck from BRP	17	18	2	6	6	5	11	53	27	26	43	52	22
	Rail from BRP	17	16	15	14	17	16	17	20	17	18	16	18	17
	Total truck	606	569	591	576	595	575	600	642	597	615	613	641	602
NSW	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	0	0	0	0	0	0	0	0	1	0	3	0	0
	Rail from BRP	24	23	23	23	23	22	24	26	24	26	25	26	24
	Total truck	0	0	0	0	0	0	0	0	1	0	3	0	0
Total	Truck from LKB	589	551	589	570	589	570	589	589	570	589	570	589	580
	Truck from BRP	17	18	2	6	6	5	11	53	28	26	46	52	23
	Rail from BRP	87	81	82	82	89	84	91	98	89	91	89	94	88
	Total truck	606	569	591	576	595	575	600	642	598	615	616	641	602

Table L-1: Transportation Trips as a Result of the Simulation model as of 2001-2005 (Cont.)

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Truck in GSP LKB Fleet (trucks)		21	23	23	23	21	21	22	22	20	21	23	21	22
Truck in BRP Fleet (trucks)		8	5	3	3	4	4	6	6	5	5	8	8	5
Rail (rails)		7	7	7	7	7	7	7	7	7	7	7	7	7
Total truck required (trucks)		29	28	26	26	25	25	28	28	25	26	31	29	27
KKN	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0
	Rail from BRP	50	44	48	45	50	48	51	51	50	51	49	52	49
	Total truck	0	0	0	0	0	0	0	0	0	0	0	0	0
LMP	Truck from LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
	Truck from BRP	47	47	21	20	30	30	73	53	55	59	71	61	47
	Rail from BRP	18	17	19	17	19	16	19	20	17	18	18	21	18
	Total truck	636	579	610	590	619	600	662	642	625	648	641	650	625
NSW	Truck from LKB	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck from BRP	6	2	1	0	3	0	0	14	5	6	12	23	6
	Rail from BRP	27	24	25	22	25	23	25	26	27	27	26	27	25
	Total truck	6	2	1	0	3	0	0	14	5	6	12	23	6
Total	Truck from LKB	589	532	589	570	589	570	589	589	570	589	570	589	578
	Truck from BRP	53	49	22	20	33	30	73	67	60	65	83	84	53
	Rail from BRP	95	85	92	84	94	87	95	97	94	96	93	100	93
	Total truck	642	581	611	590	622	600	662	656	630	654	653	673	631

Table L-1: Transportation Trips as a Result of the Simulation model as of 2001-2005 (Cont.)

Appendix M

Transportation Cost as a Result of the Simulation Model

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	8,806,424	8,111,180	8,111,180	9,038,172	8,806,424	8,574,676	9,965,164	9,733,416	9,733,416	9,038,172	9,501,668	9,965,164
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**8,806,424**	**8,111,180**	**8,111,180**	**9,038,172**	**8,806,424**	**8,574,676**	**9,965,164**	**9,733,416**	**9,733,416**	**9,038,172**	**9,501,668**	**9,965,164**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231
	Truck transportation cost from BRP	9,939,072	7,008,320	6,052,640	7,836,576	6,944,608	7,167,600	11,054,032	11,914,144	9,716,080	9,907,216	11,531,872	12,487,552
LMP	Total rail transportation cost	321,516	321,516	643,032	0	321,516	643,032	321,516	321,516	0	321,516	321,516	321,516
	Total truck transportation cost	*18,145,303*	*14,420,399*	*14,258,871*	*15,778,090*	*15,150,839*	*15,109,114*	*19,260,263*	*20,120,375*	*17,657,594*	*18,113,447*	*19,473,386*	*20,693,783*
	Total transportation cost	**18,466,819**	**14,741,915**	**14,901,903**	**15,778,090**	**15,472,355**	**15,752,146**	**19,581,779**	**20,441,891**	**17,657,594**	**18,434,963**	**19,794,902**	**21,015,299**
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	532,480	149,760	0	166,400	0	49,920	1,913,600	2,129,920	2,279,680	1,048,320	2,229,760	3,377,920
NSW	Total rail transportation cost	3,896,400	3,701,580	3,896,400	3,896,400	3,896,400	3,701,580	3,506,760	3,506,760	3,506,760	3,701,580	3,506,760	3,311,940
	Total truck transportation cost	*532,480*	*149,760*	*0*	*166,400*	*0*	*49,920*	*1,913,600*	*2,129,920*	*2,279,680*	*1,048,320*	*2,229,760*	*3,377,920*
	Total transportation cost	**4,428,880**	**3,851,340**	**3,896,400**	**4,062,800**	**3,896,400**	**3,751,500**	**5,420,360**	**5,636,680**	**5,786,440**	**4,749,900**	**5,736,520**	**6,689,860**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231
	Truck transportation cost from BRP	10,471,552	7,158,080	6,052,640	8,002,976	6,944,608	7,217,520	12,967,632	14,044,064	11,995,760	10,955,536	13,761,632	15,865,472
Total	Total rail transportation cost	13,024,340	12,134,276	12,650,612	12,934,572	13,024,340	12,919,288	13,793,440	13,561,692	13,240,176	13,061,268	13,329,944	13,598,620
	Total truck transportation cost	*18,677,783*	*14,570,159*	*14,258,871*	*15,944,490*	*15,150,839*	*15,159,034*	*21,173,863*	*22,250,295*	*19,937,274*	*19,161,767*	*21,703,146*	*24,071,703*
	Total transportation cost	**31,702,123**	**26,704,435**	**26,909,483**	**28,879,062**	**28,175,179**	**28,078,322**	**34,967,303**	**35,811,987**	**33,177,450**	**32,223,035**	**35,033,090**	**37,670,323**

Table M-1: Transportation Cost as a Result of the Simulation Model as of 2001-2005

Unit: baht

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	9,733,416	8,806,424	9,269,920	9,269,920	9,269,920	9,501,668	9,733,416	10,196,912	10,196,912	9,269,920	9,733,416	10,660,408	115,642,252	9,636,854
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**9,733,416**	**8,806,424**	**9,269,920**	**9,269,920**	**9,269,920**	**9,501,668**	**9,733,416**	**10,196,912**	**10,196,912**	**9,269,920**	**9,733,416**	**10,660,408**	**115,642,252**	**9,636,854**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,621,749	8,051,812
	Truck transportation cost from BRP	11,914,144	10,894,752	11,149,600	10,639,904	9,970,928	10,862,896	13,124,672	13,952,928	13,092,816	11,977,856	14,367,056	15,322,736	147,270,288	12,272,524
LMP	Total rail transportation cost	321,516	321,516	321,516	321,516	321,516	321,516	321,516	321,516	0	321,516	321,516	321,516	3,536,676	294,723
	Total truck transportation cost	*20,120,375*	*18,306,831*	*19,355,831*	*18,581,418*	*18,177,159*	*18,804,410*	*21,330,903*	*22,159,159*	*21,034,330*	*20,184,087*	*22,308,570*	*23,528,967*	*243,892,037*	*20,324,336*
	Total transportation cost	**20,441,891**	**18,628,347**	**19,677,347**	**18,902,934**	**18,498,675**	**19,125,926**	**21,652,419**	**22,480,675**	**21,034,330**	**20,505,603**	**22,630,086**	**23,850,483**	**247,428,713**	**20,619,059**
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	2,728,960	1,081,600	582,400	648,960	1,064,960	1,347,840	3,144,960	3,644,160	4,010,240	2,629,120	3,577,600	4,825,600	29,286,400	2,440,533
NSW	Total rail transportation cost	3,311,940	3,311,940	3,896,400	3,701,580	3,701,580	3,506,760	3,117,120	3,117,120	3,117,120	3,311,940	3,117,120	2,922,300	40,132,920	3,344,410
	Total truck transportation cost	*2,728,960*	*1,081,600*	*582,400*	*648,960*	*1,064,960*	*1,347,840*	*3,144,960*	*3,644,160*	*4,010,240*	*2,629,120*	*3,577,600*	*4,825,600*	*29,286,400*	*2,440,533*
	Total transportation cost	**6,040,900**	**4,393,540**	**4,478,800**	**4,350,540**	**4,766,540**	**4,854,600**	**6,262,080**	**6,761,280**	**7,127,360**	**5,941,060**	**6,694,720**	**7,747,900**	**69,419,320**	**5,784,943**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,621,749	8,051,812
	Truck transportation cost from BRP	14,643,104	11,976,352	11,732,000	11,288,864	11,035,888	12,210,736	16,269,632	17,597,088	17,103,056	14,606,976	17,944,656	20,148,336	176,556,688	14,713,057
Total	Total rail transportation cost	13,366,872	12,439,880	13,487,836	13,293,016	13,293,016	13,329,944	13,172,052	13,635,548	13,314,032	12,903,376	13,172,052	13,904,224	159,311,848	13,275,987
	Total truck transportation cost	*22,849,335*	*19,388,431*	*19,938,231*	*19,230,378*	*19,242,119*	*20,152,250*	*24,475,863*	*25,803,319*	*25,044,570*	*22,813,207*	*25,886,170*	*28,354,567*	*273,178,437*	*22,764,870*
	Total transportation cost	**36,216,207**	**31,828,311**	**33,426,067**	**32,523,394**	**32,535,135**	**33,482,194**	**37,647,915**	**39,438,867**	**38,358,602**	**35,716,583**	**39,058,222**	**42,258,791**	**432,490,285**	**36,040,857**

Table M-1: Transportation Cost as a Result of the Simulation Model as of 2001-2005 (Cont.)

Unit: baht

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	9,733,416	9,501,668	9,965,164	9,733,416	9,733,416	9,965,164	10,660,408	11,123,904	10,428,660	10,196,912	10,428,660	10,428,660	121,899,448	10,158,287
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**9,733,416**	**9,501,668**	**9,965,164**	**9,733,416**	**9,733,416**	**9,965,164**	**10,660,408**	**11,123,904**	**10,428,660**	**10,196,912**	**10,428,660**	**10,428,660**	**121,899,448**	**10,158,287**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,621,749	8,051,812
	Truck transportation cost from BRP	15,036,032	12,997,248	13,124,672	12,455,696	11,946,000	13,092,816	15,067,888	16,915,536	14,494,480	13,952,928	16,851,824	16,915,536	172,850,656	14,404,221
LMP	Total rail transportation cost	321,516	0	0	0	321,516	321,516	321,516	321,516	321,516	0	321,516	321,516	2,572,128	214,344
	Total truck transportation cost	*23,242,263*	*20,409,327*	*21,330,903*	*20,397,210*	*20,152,231*	*21,034,330*	*23,274,119*	*25,121,767*	*22,435,994*	*22,159,159*	*24,793,338*	*25,121,767*	*269,472,405*	*22,456,034*
	Total transportation cost	**23,563,779**	**20,409,327**	**21,330,903**	**20,397,210**	**20,473,747**	**21,355,846**	**23,595,635**	**25,443,283**	**22,757,510**	**22,159,159**	**25,114,854**	**25,443,283**	**272,044,533**	**22,670,378**
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	4,209,920	2,728,960	2,396,160	2,113,280	2,679,040	2,878,720	4,842,240	5,890,560	5,224,960	4,309,760	5,341,440	6,240,000	48,855,040	4,071,253
NSW	Total rail transportation cost	3,117,120	2,922,300	3,506,760	3,311,940	3,117,120	3,117,120	2,727,480	2,532,660	2,727,480	3,117,120	2,727,480	2,532,660	35,457,240	2,954,770
	Total truck transportation cost	*4,209,920*	*2,728,960*	*2,396,160*	*2,113,280*	*2,679,040*	*2,878,720*	*4,842,240*	*5,890,560*	*5,224,960*	*4,309,760*	*5,341,440*	*6,240,000*	*48,855,040*	*4,071,253*
	Total transportation cost	**7,327,040**	**5,651,260**	**5,902,920**	**5,425,220**	**5,796,160**	**5,995,840**	**7,569,720**	**8,423,220**	**7,952,440**	**7,426,880**	**8,068,920**	**8,772,660**	**84,312,280**	**7,026,023**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,621,749	8,051,812
	Truck transportation cost from BRP	19,245,952	15,726,208	15,520,832	14,568,976	14,625,040	15,971,536	19,910,128	22,806,096	19,719,440	18,262,688	22,193,264	23,155,536	221,705,696	18,475,475
Total	Total rail transportation cost	13,172,052	12,423,968	13,471,924	13,045,356	13,172,052	13,403,800	13,709,404	13,978,080	13,477,656	13,314,032	13,477,656	13,282,836	159,928,816	13,327,401
	Total truck transportation cost	*27,452,183*	*23,138,287*	*23,727,063*	*22,510,490*	*22,831,271*	*23,913,050*	*28,116,359*	*31,012,327*	*27,660,954*	*26,468,919*	*30,134,778*	*31,361,767*	*318,327,445*	*26,527,287*
	Total transportation cost	**40,624,235**	**35,562,255**	**37,198,987**	**35,555,846**	**36,003,323**	**37,316,850**	**41,825,763**	**44,990,407**	**41,138,610**	**39,782,951**	**43,612,434**	**44,644,603**	**478,256,261**	**39,854,688**

Table M-1: Transportation Cost as a Result of the Simulation Model as of 2001-2005 (Cont.)

Unit: baht

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	10,660,408	9,733,416	10,196,912	10,428,660	11,355,652	10,660,408	11,587,400	12,050,896	11,123,904	10,892,156	11,123,904	11,587,400	131,401,116	10,950,093
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**10,660,408**	**9,733,416**	**10,196,912**	**10,428,660**	**11,355,652**	**10,660,408**	**11,587,400**	**12,050,896**	**11,123,904**	**10,892,156**	**11,123,904**	**11,587,400**	**131,401,116**	**10,950,093**
	Truck transportation cost from GSP LKB	8,206,231	7,676,796	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,886,466	8,073,872
	Truck transportation cost from BRP	541,552	573,408	63,712	191,136	191,136	159,280	350,416	1,688,368	860,112	828,256	1,369,808	1,656,512	8,473,696	706,141
LMP	Total rail transportation cost	5,465,772	5,144,256	4,822,740	4,501,224	5,465,772	5,144,256	5,465,772	6,430,320	5,465,772	5,787,288	5,144,256	5,787,288	64,624,716	5,385,393
	Total truck transportation cost	*8,747,783*	*8,250,204*	*8,269,943*	*8,132,650*	*8,397,367*	*8,100,794*	*8,556,647*	*9,894,599*	*8,801,626*	*9,034,487*	*9,311,322*	*9,862,743*	*105,360,162*	*8,780,013*
	Total transportation cost	**14,213,555**	**13,394,460**	**13,092,683**	**12,633,874**	**13,863,139**	**13,245,050**	**14,022,419**	**16,324,919**	**14,267,398**	**14,821,775**	**14,455,578**	**15,650,031**	**169,984,878**	**14,165,406**
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	16,640	0	49,920	0	66,560	5,547
NSW	Total rail transportation cost	4,675,680	4,480,860	4,480,860	4,480,860	4,480,860	4,286,040	4,675,680	5,065,320	4,675,680	5,065,320	4,870,500	5,065,320	56,302,980	4,691,915
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*16,640*	*0*	*49,920*	*0*	*66,560*	*5,547*
	Total transportation cost	**4,675,680**	**4,480,860**	**4,480,860**	**4,480,860**	**4,480,860**	**4,286,040**	**4,675,680**	**5,065,320**	**4,692,320**	**5,065,320**	**4,920,420**	**5,065,320**	**56,369,540**	**4,697,462**
	Truck transportation cost from GSP LKB	8,206,231	7,676,796	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,886,466	8,073,872
	Truck transportation cost from BRP	541,552	573,408	63,712	191,136	191,136	159,280	350,416	1,688,368	876,752	828,256	1,419,728	1,656,512	8,540,256	711,688
Total	Total rail transportation cost	20,801,860	19,358,532	19,500,512	19,410,744	21,302,284	20,090,704	21,728,852	23,546,536	21,265,356	21,744,764	21,138,660	22,440,008	252,328,812	21,027,401
	Total truck transportation cost	*8,747,783*	*8,250,204*	*8,269,943*	*8,132,650*	*8,397,367*	*8,100,794*	*8,556,647*	*9,894,599*	*8,818,266*	*9,034,487*	*9,361,242*	*9,862,743*	*105,426,722*	*8,785,560*
	Total transportation cost	**29,549,643**	**27,608,736**	**27,770,455**	**27,543,394**	**29,699,651**	**28,191,498**	**30,285,499**	**33,441,135**	**30,083,622**	**30,779,251**	**30,499,902**	**32,302,751**	**357,755,534**	**29,812,961**

Table M-1: Transportation Cost as a Result of the Simulation Model as of 2001-2005 (Cont.)

Unit: baht

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Average
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KKN	Total rail transportation cost	11,587,400	10,196,912	11,123,904	10,428,660	11,587,400	11,123,904	11,819,148	11,819,148	11,587,400	11,819,148	11,355,652	12,050,896	136,499,572	11,374,964
	Total truck transportation cost	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total transportation cost	**11,587,400**	**10,196,912**	**11,123,904**	**10,428,660**	**11,587,400**	**11,123,904**	**11,819,148**	**11,819,148**	**11,587,400**	**11,819,148**	**11,355,652**	**12,050,896**	**136,499,572**	**11,374,964**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,621,749	8,051,812
	Truck transportation cost from BRP	1,497,232	1,497,232	668,976	637,120	955,680	955,680	2,325,488	1,688,368	1,752,080	1,879,504	2,261,776	1,943,216	18,062,352	1,505,196
LMP	Total rail transportation cost	5,787,288	5,465,772	6,108,804	5,465,772	6,108,804	5,144,256	6,108,804	6,430,320	5,465,772	5,787,288	5,787,288	6,751,836	70,412,004	5,867,667
	Total truck transportation cost	*9,703,463*	*8,909,311*	*8,875,207*	*8,578,634*	*9,161,911*	*8,897,194*	*10,531,719*	*9,894,599*	*9,693,594*	*10,085,735*	*10,203,290*	*10,149,447*	*114,684,101*	*9,557,008*
	Total transportation cost	**15,490,751**	**14,375,083**	**14,984,011**	**14,044,406**	**15,270,715**	**14,041,450**	**16,640,523**	**16,324,919**	**15,159,366**	**15,873,023**	**15,990,578**	**16,901,283**	**185,096,105**	**15,424,675**
	Truck transportation cost from GSP LKB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Truck transportation cost from BRP	99,840	33,280	16,640	0	49,920	0	0	232,960	83,200	99,840	199,680	382,720	1,198,080	99,840
NSW	Total rail transportation cost	5,260,140	4,675,680	4,870,500	4,286,040	4,870,500	4,480,860	4,870,500	5,065,320	5,260,140	5,260,140	5,065,320	5,260,140	59,225,280	4,935,440
	Total truck transportation cost	*99,840*	*33,280*	*16,640*	*0*	*49,920*	*0*	*0*	*232,960*	*83,200*	*99,840*	*199,680*	*382,720*	*1,198,080*	*99,840*
	Total transportation cost	**5,359,980**	**4,708,960**	**4,887,140**	**4,286,040**	**4,920,420**	**4,480,860**	**4,870,500**	**5,298,280**	**5,343,340**	**5,359,980**	**5,265,000**	**5,642,860**	**60,423,360**	**5,035,280**
	Truck transportation cost from GSP LKB	8,206,231	7,412,079	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	8,206,231	7,941,514	8,206,231	7,941,514	8,206,231	96,621,749	8,051,812
	Truck transportation cost from BRP	1,597,072	1,530,512	685,616	637,120	1,005,600	955,680	2,325,488	1,921,328	1,835,280	1,979,344	2,461,456	2,325,936	19,260,432	1,605,036
Total	Total rail transportation cost	22,634,828	20,338,364	22,103,208	20,180,472	22,566,704	20,749,020	22,798,452	23,314,788	22,313,312	22,866,576	22,208,260	24,062,872	266,136,856	22,178,071
	Total truck transportation cost	*9,803,303*	*8,942,591*	*8,891,847*	*8,578,634*	*9,211,831*	*8,897,194*	*10,531,719*	*10,127,559*	*9,776,794*	*10,185,575*	*10,402,970*	*10,532,167*	*115,882,181*	*9,656,848*
	Total transportation cost	**32,438,131**	**29,280,955**	**30,995,055**	**28,759,106**	**31,778,535**	**29,646,214**	**33,330,171**	**33,442,347**	**32,090,106**	**33,052,151**	**32,611,230**	**34,595,039**	**382,019,037**	**31,834,920**

Table M-1: Transportation Cost as a Result of the Simulation Model as of 2001-2005 (Cont.)

Appendix N

Transportation Cost per Unit Volume as a Result of the Simulation Model

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	17,404	16,030	16,030	17,862	17,404	16,946	19,694	19,236	19,236	17,862	18,778	19,694	18,015
KKN	Total transportation cost (baht)	8,806,424	8,111,180	8,111,180	9,038,172	8,806,424	8,574,676	9,965,164	9,733,416	9,733,416	9,038,172	9,501,668	9,965,164	9,115,421
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	14,874	12,490	13,380	13,056	13,370	13,636	15,434	15,866	14,000	14,858	15,370	16,154	14,374
LMP	Total transportation cost (baht)	18,466,819	14,741,915	14,901,903	15,778,090	15,472,355	15,752,146	19,581,779	20,441,891	17,657,594	18,434,963	19,794,902	21,015,299	17,669,971
	Transportationcost / unit volume (baht/ton)	1,242	1,180	1,114	1,208	1,157	1,155	1,269	1,288	1,261	1,241	1,288	1,301	1,225
	Total volume transported (tons)	10,712	9,834	10,200	10,360	10,200	9,738	11,020	11,228	11,372	10,698	11,324	11,918	10,717
NSW	Total transportation cost (baht)	4,428,880	3,851,340	3,896,400	4,062,800	3,896,400	3,751,500	5,420,360	5,636,680	5,786,440	4,749,900	5,736,520	6,689,860	4,825,590
	Transportationcost / unit volume (baht/ton)	413	392	382	392	382	385	492	502	509	444	507	561	447
	Total volume transported (tons)	42,990	38,354	39,610	41,278	40,974	40,320	46,148	46,330	44,608	43,418	45,472	47,766	43,106
Total	Total transportation cost (baht)	31,702,123	26,704,435	26,909,483	28,879,062	28,175,179	28,078,322	34,967,303	35,811,987	33,177,450	32,223,035	35,033,090	37,670,323	31,610,982
	Transportationcost / unit volume (baht/ton)	737	696	679	700	688	696	758	773	744	742	770	789	731

Table N-1: Transportation Cost per Unit Volume as a Result of the Simulation Model as of 2001-2005

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	19,236	17,404	18,320	18,320	18,320	18,778	19,236	20,152	20,152	18,320	19,236	21,068	19,045
KKN	Total transportation cost (baht)	9,733,416	8,806,424	9,269,920	9,269,920	9,269,920	9,501,668	9,733,416	10,196,912	10,196,912	9,269,920	9,733,416	10,660,408	9,636,854
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	15,866	14,442	15,482	14,922	14,890	15,034	16,474	16,890	15,696	15,898	16,794	17,578	15,831
LMP	Total transportation cost (baht)	20,441,891	18,628,347	19,677,347	18,902,934	18,498,675	19,125,926	21,652,419	22,480,675	21,034,330	20,505,603	22,630,086	23,850,483	20,619,059
	Transportationcost / unit volume (baht/ton)	1,288	1,290	1,271	1,267	1,242	1,272	1,314	1,331	1,340	1,290	1,348	1,357	1,301
	Total volume transported (tons)	11,294	9,710	10,760	10,314	10,714	10,476	11,184	11,664	12,016	11,198	11,600	12,290	11,102
NSW	Total transportation cost (baht)	6,040,900	4,393,540	4,478,800	4,350,540	4,766,540	4,854,600	6,262,080	6,761,280	7,127,360	5,941,060	6,694,720	7,747,900	5,784,943
	Transportationcost / unit volume (baht/ton)	535	452	416	422	445	463	560	580	593	531	577	630	517
	Total volume transported (tons)	46,396	41,556	44,562	43,556	43,924	44,288	46,894	48,706	47,864	45,416	47,630	50,936	45,977
Total	Total transportation cost (baht)	36,216,207	31,828,311	33,426,067	32,523,394	32,535,135	33,482,194	37,647,915	39,438,867	38,358,602	35,716,583	39,058,222	42,258,791	36,040,857
	Transportationcost / unit volume (baht/ton)	781	766	750	747	741	756	803	810	801	786	820	830	783

Table N-1: Transportation Cost per Unit Volume as a Result of the Simulation Model as of 2001-2005 (Cont.)

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	19,236	18,778	19,694	19,236	19,236	19,694	21,068	21,984	20,610	20,152	20,610	20,610	20,076
KKN	Total transportation cost (baht)	9,733,416	9,501,668	9,965,164	9,733,416	9,733,416	9,965,164	10,660,408	11,123,904	10,428,660	10,196,912	10,428,660	10,428,660	10,158,287
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	17,434	15,040	16,016	15,376	15,882	16,154	17,450	18,378	16,858	16,432	18,042	18,378	16,787
LMP	Total transportation cost (baht)	23,563,779	20,409,327	21,330,903	20,397,210	20,473,747	21,355,846	23,595,635	25,443,283	22,757,510	22,159,159	25,114,854	25,443,283	22,670,378
	Transportationcost / unit volume (baht/ton)	1,352	1,357	1,332	1,327	1,289	1,322	1,352	1,384	1,350	1,349	1,392	1,384	1,349
	Total volume transported (tons)	12,208	10,274	11,484	10,702	10,736	10,928	11,796	12,294	12,164	12,304	12,276	12,630	11,650
NSW	Total transportation cost (baht)	7,327,040	5,651,260	5,902,920	5,425,220	5,796,160	5,995,840	7,569,720	8,423,220	7,952,440	7,426,880	8,068,920	8,772,660	7,026,023
	Transportationcost / unit volume (baht/ton)	600	550	514	507	540	549	642	685	654	604	657	695	600
	Total volume transported (tons)	48,878	44,092	47,194	45,314	45,854	46,776	50,314	52,656	49,632	48,888	50,928	51,618	48,512
Total	Total transportation cost (baht)	40,624,235	35,562,255	37,198,987	35,555,846	36,003,323	37,316,850	41,825,763	44,990,407	41,138,610	39,782,951	43,612,434	44,644,603	39,854,688
	Transportationcost / unit volume (baht/ton)	831	807	788	785	785	798	831	854	829	814	856	865	820

Table N-1: Transportation Cost per Unit Volume as a Result of the Simulation Model as of 2001-2005 (Cont.)

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	21,068	19,236	20,152	20,610	22,442	21,068	22,900	23,816	21,984	21,526	21,984	22,900	21,641
KKN	Total transportation cost (baht)	10,660,408	9,733,416	10,196,912	10,428,660	11,355,652	10,660,408	11,587,400	12,050,896	11,123,904	10,892,156	11,123,904	11,587,400	10,950,093
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	17,482	16,432	16,326	15,628	17,306	16,528	17,386	19,432	17,338	18,084	17,136	18,500	17,298
LMP	Total transportation cost (baht)	14,213,555	13,394,460	13,092,683	12,633,874	13,863,139	13,245,050	14,022,419	16,324,919	14,267,398	14,821,775	14,455,578	15,650,031	14,165,406
	Transportationcost / unit volume (baht/ton)	813	815	802	808	801	801	807	840	823	820	844	846	819
	Total volume transported (tons)	12,240	11,730	11,730	11,730	11,730	11,220	12,240	13,260	12,256	13,260	12,798	13,260	12,288
NSW	Total transportation cost (baht)	4,675,680	4,480,860	4,480,860	4,480,860	4,480,860	4,286,040	4,675,680	5,065,320	4,692,320	5,065,320	4,920,420	5,065,320	4,697,462
	Transportationcost / unit volume (baht/ton)	382	382	382	382	382	382	382	382	383	382	384	382	382
	Total volume transported (tons)	50,790	47,398	48,208	47,968	51,478	48,816	52,526	56,508	51,578	52,870	51,918	54,660	51,227
Total	Total transportation cost (baht)	29,549,643	27,608,736	27,770,455	27,543,394	29,699,651	28,191,498	30,285,499	33,441,135	30,083,622	30,779,251	30,499,902	32,302,751	29,812,961
	Transportationcost / unit volume (baht/ton)	582	582	576	574	577	578	577	592	583	582	587	591	582

Table N-1: Transportation Cost per Unit Volume as a Result of the Simulation Model as of 2001-2005 (Cont.)

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Total volume transported (tons)	22,900	20,152	21,984	20,610	22,900	21,984	23,358	23,358	22,900	23,358	22,442	23,816	22,480
KKN	Total transportation cost (baht)	11,587,400	10,196,912	11,123,904	10,428,660	11,587,400	11,123,904	11,819,148	11,819,148	11,587,400	11,819,148	11,355,652	12,050,896	11,374,964
	Transportationcost / unit volume (baht/ton)	506	506	506	506	506	506	506	506	506	506	506	506	506
	Total volume transported (tons)	18,420	17,050	18,462	17,226	18,606	16,928	19,294	19,432	17,786	18,612	18,500	20,018	18,361
LMP	Total transportation cost (baht)	15,490,751	14,375,083	14,984,011	14,044,406	15,270,715	14,041,450	16,640,523	16,324,919	15,159,366	15,873,023	15,990,578	16,901,283	15,424,675
	Transportationcost / unit volume (baht/ton)	841	843	812	815	821	829	862	840	852	853	864	844	840
	Total volume transported (tons)	13,866	12,272	12,766	11,220	12,798	11,730	12,750	13,484	13,850	13,866	13,452	14,138	13,016
NSW	Total transportation cost (baht)	5,359,980	4,708,960	4,887,140	4,286,040	4,920,420	4,480,860	4,870,500	5,298,280	5,343,340	5,359,980	5,265,000	5,642,860	5,035,280
	Transportationcost / unit volume (baht/ton)	387	384	383	382	384	382	382	393	386	387	391	399	387
	Total volume transported (tons)	55,186	49,474	53,212	49,056	54,304	50,642	55,402	56,274	54,536	55,836	54,394	57,972	53,857
Total	Total transportation cost (baht)	32,438,131	29,280,955	30,995,055	28,759,106	31,778,535	29,646,214	33,330,171	33,442,347	32,090,106	33,052,151	32,611,230	34,595,039	31,834,920
	Transportationcost / unit volume (baht/ton)	588	592	582	586	585	585	602	594	588	592	600	597	591

Table N-1: Transportation Cost per Unit Volume as a Result of the Simulation Model as of 2001-2005 (Cont.)

Appendix O

Inventory Status as a Result of the Simulation Model

2001		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	avg. (tons)	1,055	979	1,052	993	1,004	996	907	961	974	1,009	927	897	980
	min. (tons)	394	416	447	237	308	362	197	126	261	478	211	156	299
	Planned daily demand (tons)	607	552	581	593	604	593	637	648	633	622	633	667	614
KKN	Survival days	1.74	1.77	1.81	1.68	1.66	1.68	1.42	1.48	1.54	1.62	1.46	1.35	1.60
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.06
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.79	0.00	0.08
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.79	0.00	0.08
	avg.	1,438	936	1,208	747	1,360	1,040	1,177	1,426	923	1,537	1,080	916	1,149
	min.	714	518	581	287	753	382	529	745	610	650	614	324	559
	Planned daily demand	493	441	467	463	459	459	507	522	485	493	519	537	487
LMP	Survival days	2.92	2.12	2.59	1.61	2.96	2.27	2.32	2.73	1.90	3.12	2.08	1.71	2.36
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	1,210	996	1,241	970	1,282	1,172	809	1,088	833	1,200	965	944	1,059
	min.	508	177	633	205	734	309	120	320	135	513	83	233	331
	Planned daily demand	407	367	381	367	374	374	400	419	419	407	419	426	397
NSW	Survival days	2.97	2.72	3.25	2.65	3.43	3.13	2.02	2.60	1.99	2.95	2.30	2.22	2.69
	Number of shortage	0.00	0.00	0.00	0.33	0.00	0.00	0.67	0.00	0.67	0.00	0.00	0.00	0.14
	Max. shortage hours	0.00	0.00	0.00	0.78	0.00	0.00	2.25	0.00	1.41	0.00	0.47	0.00	0.41
	Total shortage hours	0.00	0.00	0.00	0.78	0.00	0.00	2.92	0.00	2.46	0.00	0.47	0.00	0.55
	avg.	3,703	2,911	3,501	2,710	3,646	3,208	2,892	3,475	2,731	3,746	2,972	2,757	3,188
	min.	1,617	1,111	1,661	730	1,795	1,053	845	1,191	1,005	1,641	908	713	1,189
	Planned daily demand	1,507	1,359	1,430	1,422	1,437	1,426	1,544	1,589	1,537	1,522	1,570	1,630	1,498
Total	Survival days	2.46	2.14	2.45	1.91	2.54	2.25	1.87	2.19	1.78	2.46	1.89	1.69	2.14
	Number of shortage	0.00	0.00	0.00	0.33	0.00	0.00	0.67	0.33	0.67	0.00	0.33	0.00	0.19
	Max. shortage hours	0.00	0.00	0.00	0.78	0.00	0.00	2.25	0.13	1.41	0.00	1.26	0.00	0.49
	Total shortage hours	0.00	0.00	0.00	0.78	0.00	0.00	2.92	0.13	2.46	0.00	1.26	0.00	0.63

Table O-1: Inventory Status as a Result of the Simulation Model as of 2001-2005

2002		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	avg. (tons)	937	938	922	937	979	946	951	903	891	958	847	861	922
	min. (tons)	320	246	309	316	320	280	176	281	106	178	123	178	236
	Planned daily demand (tons)	644	654	635	646	637	676	670	681	724	656	696	731	671
KKN	Survival days	1.45	1.43	1.45	1.45	1.54	1.40	1.42	1.32	1.23	1.46	1.22	1.18	1.38
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.08
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.11
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.11
	avg.	1,475	962	1,025	1,222	1,363	1,078	1,330	1,237	836	1,326	1,214	949	1,168
	min.	657	602	514	653	615	590	493	589	342	541	701	393	558
	Planned daily demand	537	542	527	519	500	536	548	567	568	533	581	600	546
LMP	Survival days	2.75	1.78	1.95	2.35	2.73	2.01	2.43	2.18	1.47	2.49	2.09	1.58	2.15
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	1,080	1,017	1,127	924	1,110	902	1,139	1,164	675	1,193	1,146	932	1,034
	min.	247	244	278	181	412	270	287	426	0	448	235	216	270
	Planned daily demand	430	433	419	404	393	424	422	441	476	430	458	465	433
NSW	Survival days	2.51	2.35	2.69	2.29	2.83	2.13	2.70	2.64	1.42	2.78	2.50	2.00	2.40
	Number of shortage	0.33	0.33	0.00	0.00	0.00	0.67	0.00	0.00	1.33	0.00	0.00	0.00	0.22
	Max. shortage hours	0.80	0.31	0.00	0.00	0.00	2.03	0.00	0.00	2.90	0.00	0.22	0.00	0.52
	Total shortage hours	0.80	0.31	0.00	0.00	0.00	2.43	0.00	0.00	3.45	0.00	0.22	0.00	0.60
	avg.	3,492	2,916	3,074	3,083	3,452	2,926	3,420	3,304	2,402	3,477	3,207	2,742	3,125
	min.	1,224	1,092	1,102	1,150	1,347	1,139	955	1,296	448	1,167	1,059	787	1,064
	Planned daily demand	1,611	1,629	1,581	1,569	1,530	1,636	1,641	1,689	1,768	1,619	1,735	1,796	1,650
Total	Survival days	2.17	1.79	1.94	1.96	2.26	1.79	2.08	1.96	1.36	2.15	1.85	1.53	1.90
	Number of shortage	0.33	0.33	0.00	0.00	0.00	0.67	0.00	0.00	1.33	0.00	1.00	0.00	0.31
	Max. shortage hours	0.80	0.31	0.00	0.00	0.00	2.03	0.00	0.00	2.90	0.00	1.50	0.00	0.63
	Total shortage hours	0.80	0.31	0.00	0.00	0.00	2.43	0.00	0.00	3.45	0.00	1.51	0.00	0.71

Table O-1: Inventory Status as a Result of the Simulation Model as of 2001-2005 (Cont.)

2003		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	avg. (tons)	922	885	922	910	970	872	829	797	818	905	740	793	864
	min. (tons)	312	178	213	241	270	247	63	51	31	186	56	77	160
	Planned daily demand (tons)	678	692	669	681	670	712	704	746	731	689	760	737	706
KKN	Survival days	1.36	1.28	1.38	1.34	1.45	1.22	1.18	1.07	1.12	1.31	0.97	1.08	1.23
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	0.67	0.33	1.33	1.00	0.36
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.73	1.50	0.05	0.63	0.84	0.41
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.73	1.50	0.05	1.41	0.99	0.56
	avg.	1,284	934	1,036	1,166	1,254	865	1,165	877	1,325	1,261	976	1,448	1,133
	min.	505	507	547	684	652	359	486	262	634	525	368	603	511
	Planned daily demand	578	583	569	558	537	580	589	631	588	574	648	622	588
LMP	Survival days	2.22	1.60	1.82	2.09	2.34	1.49	1.98	1.39	2.25	2.20	1.51	2.33	1.93
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	1,155	795	859	1,079	1,111	853	1,024	978	945	1,061	871	1,177	992
	min.	287	11	20	293	155	115	109	207	294	237	44	461	186
	Planned daily demand	452	458	438	423	415	448	441	481	481	448	500	470	455
NSW	Survival days	2.56	1.73	1.96	2.55	2.68	1.90	2.32	2.03	1.97	2.37	1.74	2.50	2.19
	Number of shortage	0.00	0.67	0.67	0.33	0.00	1.33	0.33	0.67	0.33	0.33	0.33	0.00	0.42
	Max. shortage hours	0.00	1.56	2.77	1.18	0.00	2.25	0.29	0.30	0.37	2.02	0.61	0.00	0.95
	Total shortage hours	0.00	1.56	2.77	1.18	0.00	3.37	0.29	0.50	0.37	2.02	0.61	0.00	1.06
	avg.	3,362	2,615	2,817	3,156	3,336	2,590	3,017	2,652	3,088	3,227	2,588	3,418	2,989
	min.	1,104	697	780	1,218	1,077	720	658	520	959	947	469	1,141	858
	Planned daily demand	1,707	1,733	1,677	1,662	1,622	1,740	1,733	1,858	1,800	1,711	1,908	1,830	1,748
Total	Survival days	1.97	1.51	1.68	1.90	2.06	1.49	1.74	1.43	1.72	1.89	1.36	1.87	1.72
	Number of shortage	0.00	0.67	0.67	0.33	0.00	1.33	1.00	1.00	1.00	0.67	1.67	1.00	0.78
	Max. shortage hours	0.00	1.56	2.77	1.18	0.00	2.25	1.46	1.04	1.87	2.07	1.24	0.84	1.36
	Total shortage hours	0.00	1.56	2.77	1.18	0.00	3.37	2.28	1.23	1.87	2.07	2.02	0.99	1.61

Table O-1: Inventory Status as a Result of the Simulation Model as of 2001-2005 (Cont.)

2004		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	avg. (tons)	1,472	1,533	1,507	1,478	1,438	1,477	1,412	1,479	1,571	1,583	1,515	1,471	1,495
	min. (tons)	890	873	931	884	538	880	853	803	539	677	765	759	783
	Planned daily demand (tons)	711	725	678	715	731	719	741	781	765	750	765	774	738
KKN	Survival days	2.07	2.11	2.22	2.07	1.97	2.05	1.91	1.89	2.05	2.11	1.98	1.90	2.03
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	952	1,031	1,022	998	943	1,144	909	618	735	980	582	538	871
	min.	587	601	0	83	83	69	199	265	302	211	195	233	236
	Planned daily demand	622	625	585	600	600	596	630	677	627	635	665	663	627
LMP	Survival days	1.53	1.65	1.75	1.66	1.57	1.92	1.44	0.91	1.17	1.54	0.87	0.81	1.40
	Number of shortage	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
	Max. shortage hours	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	1,317	1,402	1,455	1,427	1,407	1,377	1,390	1,228	1,323	1,270	1,265	1,193	1,338
	min.	632	878	847	962	704	558	876	581	383	672	250	423	647
	Planned daily demand	474	479	444	442	450	450	463	504	504	488	500	493	474
NSW	Survival days	2.78	2.93	3.27	3.23	3.13	3.06	3.00	2.44	2.63	2.60	2.53	2.42	2.83
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	3,741	3,966	3,984	3,903	3,788	3,998	3,711	3,325	3,629	3,833	3,362	3,202	3,704
	min.	2,109	2,352	1,778	1,929	1,325	1,507	1,928	1,649	1,224	1,560	1,210	1,415	1,666
	Planned daily demand	1,807	1,829	1,707	1,758	1,781	1,765	1,833	1,962	1,896	1,873	1,931	1,930	1,839
Total	Survival days	2.07	2.17	2.33	2.22	2.13	2.26	2.02	1.70	1.91	2.05	1.74	1.66	2.02
	Number of shortage	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
	Max. shortage hours	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table O-1: Inventory Status as a Result of the Simulation Model as of 2001-2005 (Cont.)

2005		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	avg. (tons)	1,520	1,526	1,483	1,550	1,514	1,452	1,505	1,505	1,452	1,474	1,560	1,519	1,505
	min. (tons)	788	791	753	840	794	774	774	306	774	795	695	521	717
	Planned daily demand (tons)	777	763	711	750	765	754	804	789	804	785	800	807	776
KKN	Survival days	1.96	2.00	2.09	2.07	1.98	1.93	1.87	1.91	1.81	1.88	1.95	1.88	1.94
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	756	881	795	788	890	775	705	687	884	721	716	724	777
	min.	359	556	433	478	455	326	76	133	256	365	51	201	307
	Planned daily demand	688	667	626	638	638	635	700	693	669	677	708	707	671
LMP	Survival days	1.10	1.32	1.27	1.23	1.39	1.22	1.01	0.99	1.32	1.07	1.01	1.02	1.16
	Number of shortage	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00	0.00	0.25
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	2.10	0.00	0.38
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	4.76	0.00	0.61
	avg.	1,214	1,256	1,252	1,374	1,346	1,428	1,267	1,127	1,205	1,147	1,146	973	1,228
	min.	0	294	400	704	259	872	629	336	200	90	181	138	342
	Planned daily demand	515	504	467	465	473	473	504	507	527	512	523	515	499
NSW	Survival days	2.36	2.49	2.68	2.95	2.85	3.02	2.51	2.22	2.29	2.24	2.19	1.89	2.47
	Number of shortage	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	avg.	3,490	3,663	3,530	3,712	3,750	3,655	3,477	3,319	3,541	3,342	3,422	3,216	3,510
	min.	1,147	1,641	1,586	2,022	1,508	1,972	1,479	775	1,230	1,250	927	860	1,366
	Planned daily demand	1,981	1,933	1,804	1,854	1,877	1,862	2,008	1,989	2,000	1,973	2,031	2,030	1,945
Total	Survival days	1.76	1.89	1.96	2.00	2.00	1.96	1.73	1.67	1.77	1.69	1.69	1.58	1.81
	Number of shortage	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00	0.00	0.33
	Max. shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	2.10	0.00	0.38
	Total shortage hours	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	4.76	0.00	0.61

Table O-1: Inventory Status as a Result of the Simulation Model as of 2001-2005 (Cont.)

Appendix P

Monthly Demand as a Result of the Simulation Model Compared with Those of Plan

Unit: tons

KKN 2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	16,400	14,900	15,700	16,000	16,300	16,000	17,200	17,500	17,100	16,800	17,100	18,000	16,583
Actual monthly demand from simulation	17,585	15,510	16,230	17,674	17,093	16,800	19,973	19,453	18,942	17,835	18,648	20,125	17,989
Planned daily demand	607	552	581	593	604	593	637	648	633	622	633	667	614
Actual daily demand from simulation	651	574	601	655	633	622	740	720	702	661	691	745	666
% different from plan	7.22	4.10	3.38	10.46	4.87	5.00	16.12	11.16	10.77	6.16	9.05	11.81	8.34

Unit: tons

LMP 2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	13,300	11,900	12,600	12,500	12,400	12,400	13,700	14,100	13,100	13,300	14,000	14,500	13,150
Actual monthly demand from simulation	13,741	12,107	12,953	13,183	12,717	12,804	14,600	14,571	13,836	13,716	14,773	15,520	13,710
Planned daily demand	493	441	467	463	459	459	507	522	485	493	519	537	487
Actual daily demand from simulation	509	448	480	488	471	474	541	540	512	508	547	575	508
% different from plan	3.31	1.74	2.80	5.46	2.56	3.26	6.57	3.34	5.62	3.13	5.52	7.03	4.19

Unit: tons

NSW 2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	11,000	9,900	10,300	9,900	10,100	10,100	10,800	11,300	11,300	11,000	11,300	11,500	10,708
Actual monthly demand from simulation	10,531	9,683	10,094	10,259	9,696	9,747	10,860	10,876	11,582	10,673	11,226	11,704	10,578
Planned daily demand	407	367	381	367	374	374	400	419	419	407	419	426	397
Actual daily demand from simulation	390	359	374	380	359	361	402	403	429	395	416	433	392
% different from plan	-4.27	-2.20	-2.00	3.63	-4.00	-3.49	0.56	-3.75	2.49	-2.98	-0.65	1.77	-1.24

Unit: tons

Total 2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	40,700	36,700	38,600	38,400	38,800	38,500	41,700	42,900	41,500	41,100	42,400	44,000	40,442
Actual monthly demand from simulation	41,856	37,300	39,278	41,117	39,506	39,351	45,433	44,900	44,360	42,224	44,647	47,349	42,277
Working days	27	27	27	27	27	27	27	27	27	27	27	27	27
Planned daily demand	1,507	1,359	1,430	1,422	1,437	1,426	1,544	1,589	1,537	1,522	1,570	1,630	1,498
Actual daily demand from simulation	1,550	1,381	1,455	1,523	1,463	1,457	1,683	1,663	1,643	1,564	1,654	1,754	1,566
% different from plan	2.84	1.63	1.76	7.07	1.82	2.21	8.95	4.66	6.89	2.73	5.30	7.61	4.46

Table P-1: Monthly Demand as a Result of the Simulation Model Compared with Those of Plan

Unit: tons

KKN 2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	17,400	15,700	16,500	16,800	17,200	16,900	18,100	18,400	18,100	17,700	18,100	19,000	17,492
Actual monthly demand from simulation	19,321	16,784	18,793	18,178	18,637	18,702	19,266	19,914	20,143	18,771	19,298	21,097	19,075
Planned daily demand	644	654	635	646	637	676	670	681	724	656	696	731	671
Actual daily demand from simulation	716	699	723	699	690	748	714	738	806	695	742	811	732
% different from plan	11.04	6.90	13.89	8.20	8.35	10.66	6.44	8.23	11.29	6.05	6.62	11.04	9.06

Unit: tons

LMP 2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	14,500	13,000	13,700	13,500	13,500	13,400	14,800	15,300	14,200	14,400	15,100	15,600	14,250
Actual monthly demand from simulation	14,757	13,516	14,924	13,931	14,052	14,233	15,401	15,961	15,311	14,964	15,676	16,911	14,970
Planned daily demand	537	542	527	519	500	536	548	567	568	533	581	600	546
Actual daily demand from simulation	547	563	574	536	520	569	570	591	612	554	603	650	574
% different from plan	1.77	3.97	8.93	3.19	4.09	6.22	4.06	4.32	7.82	3.92	3.81	8.40	5.04

Unit: tons

NSW 2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	11,600	10,400	10,900	10,500	10,600	10,600	11,400	11,900	11,900	11,600	11,900	12,100	11,283
Actual monthly demand from simulation	11,232	9,894	10,814	10,225	10,338	10,639	11,260	11,478	12,220	11,271	11,738	12,390	11,125
Planned daily demand	430	433	419	404	393	424	422	441	476	430	458	465	433
Actual daily demand from simulation	416	412	416	393	383	426	417	425	489	417	451	477	427
% different from plan	-3.17	-4.87	-0.79	-2.62	-2.47	0.37	-1.23	-3.55	2.69	-2.84	-1.36	2.39	-1.45

Unit: tons

Total 2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	43,500	39,100	41,100	40,800	41,300	40,900	44,300	45,600	44,200	43,700	45,100	46,700	43,025
Actual monthly demand from simulation	45,310	40,194	44,530	42,333	43,027	43,575	45,927	47,352	47,674	45,006	46,712	50,398	45,170
Working days	27	24	26	26	27	25	27	27	25	27	26	26	26
Planned daily demand	1,611	1,629	1,581	1,569	1,530	1,636	1,641	1,689	1,768	1,619	1,735	1,796	1,650
Actual daily demand from simulation	1,678	1,675	1,713	1,628	1,594	1,743	1,701	1,754	1,907	1,667	1,797	1,938	1,733
% different from plan	4.16	2.80	8.35	3.76	4.18	6.54	3.67	3.84	7.86	2.99	3.58	7.92	4.97

Table P-1: Monthly Demand as a Result of the Simulation Model Compared with Those of Plan (Cont.)

Unit: tons

KKN 2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	18,300	16,600	17,400	17,700	18,100	17,800	19,000	19,400	19,000	18,600	19,000	19,900	18,400
Actual monthly demand from simulation	19,550	17,944	19,791	19,072	19,503	19,556	21,047	22,287	20,390	19,934	20,583	20,776	20,036
Planned daily demand	678	692	669	681	670	712	704	746	731	689	760	737	706
Actual daily demand from simulation	724	748	761	734	722	782	780	857	784	738	823	769	769
% different from plan	6.83	8.10	13.74	7.75	7.75	9.87	10.77	14.88	7.32	7.17	8.33	4.40	8.91

Unit: tons

LMP 2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	15,600	14,000	14,800	14,500	14,500	14,500	15,900	16,400	15,300	15,500	16,200	16,800	15,333
Actual monthly demand from simulation	16,211	14,522	15,651	14,902	14,803	15,712	16,566	17,820	15,582	15,726	17,466	17,204	16,014
Planned daily demand	578	583	569	558	537	580	589	631	588	574	648	622	588
Actual daily demand from simulation	600	605	602	573	548	628	614	685	599	582	699	637	614
% different from plan	3.91	3.73	5.75	2.77	2.09	8.36	4.19	8.66	1.84	1.46	7.81	2.40	4.42

Unit: tons

NSW 2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	12,200	11,000	11,400	11,000	11,200	11,200	11,900	12,500	12,500	12,100	12,500	12,700	11,850
Actual monthly demand from simulation	12,016	10,867	11,927	10,792	10,663	11,113	11,661	12,390	11,947	12,082	12,558	12,532	11,712
Planned daily demand	452	458	438	423	415	448	441	481	481	448	500	470	455
Actual daily demand from simulation	445	453	459	415	395	445	432	477	460	447	502	464	449
% different from plan	-1.51	-1.21	4.62	-1.89	-4.80	-0.78	-2.01	-0.88	-4.42	-0.15	0.46	-1.32	-1.16

Unit: tons

Total 2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	46,100	41,600	43,600	43,200	43,800	43,500	46,800	48,300	46,800	46,200	47,700	49,400	45,583
Actual monthly demand from simulation	47,776	43,333	47,369	44,766	44,969	46,381	49,274	52,498	47,919	47,742	50,607	50,512	47,762
Working days	27	24	26	26	27	25	27	26	26	27	25	27	26
Planned daily demand	1,707	1,733	1,677	1,662	1,622	1,740	1,733	1,858	1,800	1,711	1,908	1,830	1,748
Actual daily demand from simulation	1,769	1,806	1,822	1,722	1,666	1,855	1,825	2,019	1,843	1,768	2,024	1,871	1,832
% different from plan	3.64	4.17	8.65	3.62	2.67	6.62	5.29	8.69	2.39	3.34	6.09	2.25	4.78

Table P-1: Monthly Demand as a Result of the Simulation Model Compared with Those of Plan (Cont.)

Unit: tons

KKN 2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	19,200	17,400	18,300	18,600	19,000	18,700	20,000	20,300	19,900	19,500	19,900	20,900	19,308
Actual monthly demand from simulation	20,747	18,596	19,365	19,864	22,160	20,160	22,662	23,259	21,124	21,593	21,728	22,472	21,144
Planned daily demand	711	725	678	715	731	719	741	781	765	750	765	774	738
Actual daily demand from simulation	768	775	717	764	852	775	839	895	812	831	836	832	808
% different from plan	8.06	6.87	5.82	6.80	16.63	7.81	13.31	14.58	6.15	10.73	9.19	7.52	9.46

Unit: tons

LMP 2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	16,800	15,000	15,800	15,600	15,600	15,500	17,000	17,600	16,300	16,500	17,300	17,900	16,408
Actual monthly demand from simulation	17,338	15,715	16,615	16,005	16,779	16,104	17,206	18,974	17,024	17,894	16,963	18,921	17,128
Planned daily demand	622	625	585	600	600	596	630	677	627	635	665	663	627
Actual daily demand from simulation	642	655	615	616	645	619	637	730	655	688	652	701	655
% different from plan	3.20	4.77	5.16	2.60	7.56	3.90	1.21	7.81	4.44	8.45	-1.95	5.70	4.40

Unit: tons

NSW 2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	12,800	11,500	12,000	11,500	11,700	11,700	12,500	13,100	13,100	12,700	13,000	13,300	12,408
Actual monthly demand from simulation	12,459	11,463	11,577	11,142	11,903	11,464	12,137	13,462	12,469	12,899	12,702	12,973	12,221
Planned daily demand	474	479	444	442	450	450	463	504	504	488	500	493	474
Actual daily demand from simulation	461	478	429	429	458	441	450	518	480	496	489	480	467
% different from plan	-2.66	-0.32	-3.53	-3.11	1.74	-2.02	-2.90	2.76	-4.82	1.57	-2.29	-2.46	-1.50

Unit: tons

Total 2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	48,800	43,900	46,100	45,700	46,300	45,900	49,500	51,000	49,300	48,700	50,200	52,100	48,125
Actual monthly demand from simulation	50,544	45,774	47,557	47,011	50,842	47,728	52,005	55,695	50,617	52,386	51,393	54,366	50,493
Working days	27	24	27	26	26	26	27	26	26	26	26	27	26
Planned daily demand	1,807	1,829	1,707	1,758	1,781	1,765	1,833	1,962	1,896	1,873	1,931	1,930	1,839
Actual daily demand from simulation	1,872	1,907	1,761	1,808	1,955	1,836	1,926	2,142	1,947	2,015	1,977	2,014	1,930
% different from plan	3.57	4.27	3.16	2.87	9.81	3.98	5.06	9.21	2.67	7.57	2.38	4.35	4.91

Table P-1: Monthly Demand as a Result of the Simulation Model Compared with Those of Plan (Cont.)

Unit: tons

KKN 2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	20,200	18,300	19,200	19,500	19,900	19,600	20,900	21,300	20,900	20,400	20,800	21,800	20,233
Actual monthly demand from simulation	22,805	19,965	21,388	20,321	22,203	21,380	22,428	22,330	22,382	22,945	21,822	23,341	21,943
Planned daily demand	777	763	711	750	765	754	804	789	804	785	800	807	776
Actual daily demand from simulation	877	832	792	782	854	822	863	827	861	883	839	864	841
% different from plan	12.90	9.10	11.40	4.21	11.57	9.08	7.31	4.84	7.09	12.48	4.91	7.07	8.50

Unit: tons

LMP 2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	17,900	16,000	16,900	16,600	16,600	16,500	18,200	18,700	17,400	17,600	18,400	19,100	17,492
Actual monthly demand from simulation	19,442	16,617	18,054	16,851	18,411	16,677	20,157	19,506	17,868	18,314	19,021	20,025	18,412
Planned daily demand	688	667	626	638	638	635	700	693	669	677	708	707	671
Actual daily demand from simulation	748	692	669	648	708	641	775	722	687	704	732	742	706
% different from plan	8.61	3.86	6.83	1.51	10.91	1.07	10.75	4.31	2.69	4.06	3.38	4.84	5.24

Unit: tons

NSW 2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	13,400	12,100	12,600	12,100	12,300	12,300	13,100	13,700	13,700	13,300	13,600	13,900	13,008
Actual monthly demand from simulation	13,364	11,626	12,693	11,812	12,158	11,815	12,975	13,248	13,698	13,528	13,537	13,572	12,836
Planned daily demand	515	504	467	465	473	473	504	507	527	512	523	515	499
Actual daily demand from simulation	514	484	470	454	468	454	499	491	527	520	521	503	492
% different from plan	-0.27	-3.92	0.74	-2.38	-1.15	-3.94	-0.95	-3.30	-0.01	1.71	-0.46	-2.36	-1.36

Unit: tons

Total 2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Planned monthly demand	51,500	46,400	48,700	48,200	48,800	48,400	52,200	53,700	52,000	51,300	52,800	54,800	50,733
Actual monthly demand from simulation	55,611	48,208	52,135	48,984	52,772	49,872	55,560	55,084	53,948	54,787	54,380	56,938	53,190
Working days	26	24	27	26	26	26	26	27	26	26	26	27	26
Planned daily demand	1,981	1,933	1,804	1,854	1,877	1,862	2,008	1,989	2,000	1,973	2,031	2,030	1,945
Actual daily demand from simulation	2,139	2,009	1,931	1,884	2,030	1,918	2,137	2,040	2,075	2,107	2,092	2,109	2,039
% different from plan	7.98	3.90	7.05	1.63	8.14	3.04	6.44	2.58	3.75	6.80	2.99	3.90	4.85

Table P-1: Monthly Demand as a Result of the Simulation Model Compared with Those of Plan (Cont.)

Appendix Q

Resource Utilization Based on Total Simulation Time

Unit: %

2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	40.17	41.14	39.28	41.85	39.89	40.32	42.13	40.88	42.12	40.00	42.03	41.48	40.94
Truck loading bay @ BRP	17.18	12.67	9.44	13.20	10.87	11.77	23.07	24.98	22.74	18.66	25.54	29.61	18.31
Truck loading bay @ LKB	17.90	17.92	17.92	17.91	17.94	17.93	17.87	17.91	17.91	17.90	17.89	17.87	17.91
Rail unloading bay @ KKN	40.85	41.20	37.19	42.87	39.59	40.71	45.54	45.17	45.86	41.11	44.98	46.38	42.62
Rail unloading bay @ LMP	0.75	1.22	2.55	0.36	1.12	1.88	0.69	0.72	0.00	1.13	0.75	0.74	0.99
Rail unloading bay @ NSW	21.21	21.62	21.11	20.82	20.79	20.42	18.33	18.07	19.33	20.50	18.91	17.43	19.88
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	39.63	36.67	34.28	37.14	35.53	36.20	41.06	42.27	39.69	39.57	42.26	43.11	38.95
Truck unloading bay @ NSW	2.14	0.67	0.00	0.66	0.02	0.18	7.69	8.54	9.45	4.23	9.24	13.50	4.69
Rail	64.48	66.26	63.53	66.75	64.07	65.71	67.47	66.48	67.54	64.68	66.69	67.31	65.91
Truck in BRP fleet	43.62	51.54	38.17	32.04	41.70	33.54	34.34	43.72	34.77	43.15	41.81	34.09	39.37
Truck in LKN fleet	32.93	33.05	32.80	34.34	32.87	32.86	32.83	32.78	34.41	31.50	31.54	32.77	32.89

Table Q-1: Resource Utilization as a Result of the Simulation Model Based on Total Simulation Time

Unit: %

2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	40.60	41.08	41.57	41.71	40.53	41.65	39.89	40.71	42.20	39.47	41.53	41.77	41.06
Truck loading bay @ BRP	26.84	22.51	19.18	19.26	18.82	21.74	29.99	32.76	33.62	26.59	34.28	38.79	27.03
Truck loading bay @ LKB	17.88	17.94	17.90	17.91	17.90	17.91	17.91	17.91	17.92	17.90	17.93	17.89	17.91
Rail unloading bay @ KKN	44.69	44.10	42.40	43.26	42.38	44.78	43.59	46.00	48.70	43.03	46.42	47.99	44.78
Rail unloading bay @ LMP	1.07	0.35	0.74	0.74	1.05	0.78	1.16	1.09	0.00	1.04	0.37	0.36	0.73
Rail unloading bay @ NSW	17.40	20.04	21.01	19.97	19.83	18.86	17.68	16.14	16.59	17.70	16.94	16.48	18.22
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	42.25	42.39	41.20	41.03	39.64	41.35	43.89	45.05	44.40	42.34	46.16	46.88	43.05
Truck unloading bay @ NSW	10.96	4.79	2.33	2.72	4.29	5.62	12.60	14.60	16.68	10.52	14.80	19.33	9.94
Rail	65.88	67.06	66.85	66.76	66.03	67.27	64.94	66.66	67.60	64.35	66.77	68.00	66.52
Truck in BRP fleet	42.76	42.10	41.23	42.29	40.51	37.55	40.07	43.54	35.99	40.52	46.17	42.30	41.25
Truck in LKN fleet	32.84	32.96	32.92	31.55	32.83	31.44	34.42	34.26	31.55	34.45	34.32	31.69	32.94

Table Q-1: Resource Utilization as a Result of the Simulation Model Based on Total Simulation Time (Cont.)

Unit: %

2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	39.84	41.97	41.70	43.15	40.42	41.97	40.75	41.90	43.28	40.86	41.54	40.34	41.48
Truck loading bay @ BRP	36.13	31.60	27.75	26.67	26.65	30.03	38.16	44.17	39.56	34.74	43.80	45.13	35.37
Truck loading bay @ LKB	17.92	17.89	17.95	17.95	17.91	17.93	17.97	17.89	17.92	17.89	17.89	17.91	17.92
Rail unloading bay @ KKN	44.45	46.33	45.39	45.99	44.74	46.66	47.62	50.68	49.07	46.41	49.54	47.32	47.02
Rail unloading bay @ LMP	0.67	0.44	0.39	0.36	1.12	0.79	0.73	0.71	0.75	0.31	0.79	1.10	0.68
Rail unloading bay @ NSW	16.96	17.84	19.01	17.76	17.54	16.81	14.76	13.06	14.37	17.10	14.43	13.82	16.12
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	46.56	45.51	43.82	43.47	42.30	44.43	47.28	49.09	46.36	45.00	49.72	49.03	46.05
Truck unloading bay @ NSW	16.81	12.06	9.57	8.71	10.71	11.93	19.43	23.55	21.56	17.31	22.10	25.00	16.56
Rail	64.84	67.82	67.25	66.85	65.36	67.27	66.41	67.84	67.38	65.60	67.64	65.31	66.63
Truck in BRP fleet	42.88	41.52	38.55	41.20	42.72	37.46	43.45	43.43	44.33	43.04	40.95	48.26	42.32
Truck in LKN fleet	32.89	31.55	32.84	34.37	31.48	31.41	31.53	32.10	31.61	32.88	31.99	33.00	32.30

Table Q-1: Resource Utilization as a Result of the Simulation Model Based on Total Simulation Time (Cont.)

Unit: %

2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	59.15	59.33	55.57	57.15	61.00	58.72	62.10	67.01	63.12	61.71	62.09	64.19	60.93
Truck loading bay @ BRP	0.86	0.99	0.10	0.32	0.30	0.25	0.55	2.65	1.47	1.34	2.36	2.61	1.15
Truck loading bay @ LKB	17.92	17.87	17.88	17.91	17.90	17.90	17.90	17.92	17.93	17.96	17.89	17.95	17.91
Rail unloading bay @ KKN	49.53	46.65	43.97	48.36	51.68	49.19	53.39	55.13	50.52	49.49	51.64	51.73	50.11
Rail unloading bay @ LMP	18.19	18.72	16.40	15.94	17.91	16.72	18.10	19.71	18.94	18.67	18.31	19.80	18.12
Rail unloading bay @ NSW	24.22	27.44	25.09	26.49	24.59	25.29	25.31	28.22	26.01	26.04	28.43	28.56	26.31
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	26.84	26.86	26.21	26.31	26.34	26.39	26.63	28.52	27.36	27.35	28.15	28.51	27.12
Truck unloading bay @ NSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.21	0.00	0.02
Rail	60.78	61.19	55.17	58.21	62.50	59.39	63.00	67.43	64.98	61.81	64.14	65.56	62.01
Truck in BRP fleet	5.81	10.65	0.00	5.99	3.08	2.48	7.00	36.10	20.25	12.86	17.21	22.02	11.95
Truck in LKN fleet	32.90	36.06	40.26	37.08	37.18	34.22	39.10	47.78	38.63	38.83	36.24	44.60	38.57

Table Q-1: Resource Utilization as a Result of the Simulation Model Based on Total Simulation Time (Cont.)

Unit: %

2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	64.52	63.97	62.96	58.30	64.30	61.15	64.99	66.34	65.66	65.65	65.49	67.96	64.27
Truck loading bay @ BRP	2.67	2.69	1.11	1.06	1.67	1.58	3.66	337.00	3.09	3.25	4.29	4.19	30.52
Truck loading bay @ LKB	17.89	17.93	17.90	17.89	17.94	17.91	17.94	17.88	17.85	17.89	17.90	17.87	17.90
Rail unloading bay @ KKN	52.12	51.64	50.33	48.00	52.58	50.88	53.03	53.91	55.36	54.31	52.03	55.00	52.43
Rail unloading bay @ LMP	19.77	17.70	20.02	19.06	19.08	18.07	20.71	20.69	19.06	18.55	20.38	21.72	19.57
Rail unloading bay @ NSW	28.07	27.25	27.54	24.37	27.69	26.14	26.19	27.42	30.04	27.49	29.15	28.62	27.50
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	28.26	28.51	27.05	27.14	27.48	27.50	29.37	28.50	28.69	28.71	29.41	28.90	28.29
Truck unloading bay @ NSW	0.39	15.00	0.07	0.00	0.02	0.00	0.00	0.91	0.34	0.41	0.84	1.55	1.63
Rail	66.19	64.59	64.82	59.79	66.10	62.54	66.70	68.67	66.15	66.37	67.17	70.29	65.78
Truck in BRP fleet	20.70	33.08	0.00	0.00	0.00	26.01	29.02	0.00	35.51	40.81	33.03	31.04	20.77
Truck in LKN fleet	35.86	33.07	32.90	32.92	35.86	38.42	34.33	34.37	47.74	41.94	32.82	36.06	36.36

Table Q-1: Resource Utilization as a Result of the Simulation Model Based on Total Simulation Time (Cont.)

Appendix R

Resource Utilization Based on Total Working Hours

Unit: %

2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	60.26	61.71	58.92	62.78	59.84	60.48	63.19	61.32	63.18	60.01	63.05	62.22	61.41
Truck loading bay @ BRP	25.78	19.00	14.17	19.80	16.31	17.66	34.61	37.47	34.11	28.00	38.31	44.42	27.47
Truck loading bay @ LKB	17.90	17.92	17.92	17.91	17.94	17.93	17.87	17.91	17.91	17.90	17.89	17.87	17.91
Rail unloading bay @ KKN	61.28	61.80	55.78	64.31	59.39	61.06	68.31	67.75	68.80	61.67	67.47	69.58	63.93
Rail unloading bay @ LMP	1.12	1.84	3.82	0.54	1.68	2.82	1.04	1.08	0.00	1.69	1.13	1.12	1.49
Rail unloading bay @ NSW	31.82	32.43	31.67	31.24	31.18	30.64	27.50	27.11	28.99	30.76	28.37	26.15	29.82
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	59.45	55.01	51.42	55.72	53.30	54.31	61.59	63.41	59.54	59.35	63.40	64.67	58.43
Truck unloading bay @ NSW	3.21	1.01	0.00	0.99	0.04	0.28	11.54	12.82	14.18	6.35	13.86	20.25	7.04
Rail	64.48	66.26	63.53	66.75	64.07	65.71	67.47	66.48	67.54	64.68	66.69	67.31	65.91
Truck in BRP fleet	43.62	51.54	38.17	32.04	41.70	33.54	34.34	43.72	34.77	43.15	41.81	34.09	39.37
Truck in LKN fleet	32.93	33.05	32.80	34.34	32.87	32.86	32.83	32.78	34.41	31.50	31.54	32.77	32.89

Table R-1: Resource Utilization as a Result of the Simulation Model Based on Total Working Hours

Unit: %

2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	60.91	61.63	62.36	62.56	60.80	62.47	59.84	61.07	63.31	59.21	62.29	62.66	61.59
Truck loading bay @ BRP	40.26	33.77	28.78	28.89	28.23	32.62	44.98	49.14	50.43	39.89	51.43	58.19	40.55
Truck loading bay @ LKB	17.88	17.94	17.90	17.91	17.90	17.91	17.91	17.91	17.92	17.90	17.93	17.89	17.91
Rail unloading bay @ KKN	67.04	66.16	63.61	64.89	63.57	67.18	65.39	69.00	73.05	64.55	69.63	71.98	67.17
Rail unloading bay @ LMP	1.61	0.53	1.12	1.12	1.57	1.17	1.74	1.64	0.00	1.56	0.56	0.54	1.09
Rail unloading bay @ NSW	26.11	30.07	31.52	29.96	29.74	28.29	26.52	24.21	24.88	26.56	25.42	24.72	27.33
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	63.37	63.59	61.80	61.55	59.46	62.03	65.84	67.58	66.61	63.51	69.25	70.33	64.57
Truck unloading bay @ NSW	16.44	7.19	3.49	4.08	6.44	8.43	18.90	21.90	25.02	15.79	22.21	29.00	14.90
Rail	65.88	67.06	66.85	66.76	66.03	67.27	64.94	66.66	67.60	64.35	66.77	68.00	66.52
Truck in BRP fleet	42.76	42.10	41.23	42.29	40.51	37.55	40.07	43.54	35.99	40.52	46.17	42.30	41.25
Truck in LKN fleet	32.84	32.96	32.92	31.55	32.83	31.44	34.42	34.26	31.55	34.45	34.32	31.69	32.94

Table R-1: Resource Utilization as a Result of the Simulation Model Based on Total Working Hours (Cont.)

Unit: %

2003	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	59.76	62.95	62.56	64.73	60.63	62.95	61.13	62.85	64.92	61.30	62.31	60.52	62.22
Truck loading bay @ BRP	54.20	47.40	41.62	40.00	39.98	45.05	57.24	66.26	59.34	52.12	65.70	67.70	53.05
Truck loading bay @ LKB	17.92	17.89	17.95	17.95	17.91	17.93	17.97	17.89	17.92	17.89	17.89	17.91	17.92
Rail unloading bay @ KKN	66.68	69.50	68.09	68.98	67.11	69.99	71.43	76.02	73.60	69.62	74.31	70.98	70.52
Rail unloading bay @ LMP	1.00	0.66	0.59	0.55	1.68	1.18	1.10	1.06	1.13	0.47	1.18	1.65	1.02
Rail unloading bay @ NSW	25.45	26.77	28.52	26.64	26.31	25.21	22.14	19.59	21.56	25.65	21.65	20.73	24.18
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	69.85	68.27	65.74	65.21	63.45	66.65	70.92	73.64	69.55	67.50	74.58	73.55	69.07
Truck unloading bay @ NSW	25.22	18.10	14.36	13.07	16.06	17.89	29.15	35.33	32.34	25.97	33.15	37.50	24.84
Rail	64.84	67.82	67.25	66.85	65.36	67.27	66.41	67.84	67.38	65.60	67.64	65.31	66.63
Truck in BRP fleet	42.88	41.52	38.55	41.20	42.72	37.46	43.45	43.43	44.33	43.04	40.95	48.26	42.32
Truck in LKN fleet	32.89	31.55	32.84	34.37	31.48	31.41	31.53	32.10	31.61	32.88	31.99	33.00	32.30

Table R-1: Resource Utilization as a Result of the Simulation Model Based on Total Working Hours (Cont.)

Unit: %

2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	88.73	89.00	83.36	85.73	91.50	88.08	93.15	100.52	94.68	92.57	93.14	96.29	91.39
Truck loading bay @ BRP	1.29	1.49	0.15	0.48	0.45	0.38	0.83	3.98	2.21	2.01	3.54	3.92	1.73
Truck loading bay @ LKB	17.92	17.87	17.88	17.91	17.90	17.90	17.90	17.92	17.93	17.96	17.89	17.95	17.91
Rail unloading bay @ KKN	74.30	69.98	65.96	72.54	77.52	73.79	80.09	82.70	75.78	74.24	77.46	77.60	75.16
Rail unloading bay @ LMP	27.29	28.08	24.60	23.91	26.87	25.08	27.15	29.57	28.41	28.01	27.47	29.70	27.18
Rail unloading bay @ NSW	36.33	41.16	37.64	39.74	36.89	37.94	37.97	42.33	39.02	39.06	42.65	42.84	39.46
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	40.26	40.29	39.32	39.47	39.51	39.59	39.95	42.78	41.04	41.03	42.23	42.77	40.68
Truck unloading bay @ NSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.32	0.00	0.04
Rail	60.78	61.19	55.17	58.21	62.50	59.39	63.00	67.43	64.98	61.81	64.14	65.56	62.01
Truck in BRP fleet	5.81	10.65	0.00	5.99	3.08	2.48	7.00	36.10	20.25	12.86	17.21	22.02	11.95
Truck in LKN fleet	32.90	36.06	40.26	37.08	37.18	34.22	39.10	47.78	38.63	38.83	36.24	44.60	38.57

Table R-1: Resource Utilization as a Result of the Simulation Model Based on Total Working Hours (Cont.)

Unit: %

2005	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Rail loading bay @ BRP	96.78	95.96	94.44	87.45	96.45	91.73	97.49	99.51	98.49	98.48	98.24	101.94	96.41
Truck loading bay @ BRP	4.01	4.04	1.67	1.59	2.51	2.37	5.49	505.50	4.64	4.88	6.44	6.29	45.78
Truck loading bay @ LKB	17.89	17.93	17.90	17.89	17.94	17.91	17.94	17.88	17.85	17.89	17.90	17.87	17.90
Rail unloading bay @ KKN	78.18	77.46	75.50	72.00	78.87	76.32	79.55	80.87	83.04	81.47	78.05	82.50	78.65
Rail unloading bay @ LMP	29.66	26.55	30.03	28.59	28.62	27.11	31.07	31.04	28.59	27.83	30.57	32.58	29.35
Rail unloading bay @ NSW	42.11	40.88	41.31	36.56	41.54	39.21	39.29	41.13	45.06	41.24	43.73	42.93	41.25
Truck unloading bay @ KKN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Truck unloading bay @ LMP	42.39	42.77	40.58	40.71	41.22	41.25	44.06	42.75	43.04	43.07	44.12	43.35	42.44
Truck unloading bay @ NSW	0.59	22.50	0.11	0.00	0.03	0.00	0.00	1.37	0.51	0.62	1.26	2.33	2.44
Rail	66.19	64.59	64.82	59.79	66.10	62.54	66.70	68.67	66.15	66.37	67.17	70.29	65.78
Truck in BRP fleet	20.70	33.08	0.00	0.00	0.00	26.01	29.02	0.00	35.51	40.81	33.03	31.04	20.77
Truck in LKN fleet	35.86	33.07	32.90	32.92	35.86	38.42	34.33	34.37	47.74	41.94	32.82	36.06	36.36

Table R-1: Resource Utilization as a Result of the Simulation Model Based on Total Working Hours (Cont.)

Biography

Miss Rajsuda Rungsiyakull was born on August 5, 1975 in Bangkok. She graduated from the Department of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, in 1996. Since then, she worked for Petroleum Authority of Thailand as an engineer in Supply Chain Operation Department. In 1998, she continued her studies for her Master Degree in Engineering Management, the Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University.