FLEET OPTIMIZATION OF THE PETROL TANKER

by

Ms. Pongsri Sirithattamrong

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

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
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The Graduate School of Assumption University has approved this final report of the three-credit course, CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This report concentrates on calculating the optimal number of the petrol tankers to minimize the transportation cost. The author studied in the case of the transportation of oil products to customers in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong, the using linear programming technique and the sensitivity analysis as analytical tools. Steps in study: Firstly, the study is about transportation system of the oil company, Secondly, the study of the factors that effect to design the route model of tankers and formulate the linear programming model. Thirdly, the planning and designing the tanker's route model to estimate the number of trips that the tanker can operate per day. Fourthly, the formulation the linear programming model to obtain the optimal number of tankers in upcountry depots. Finally, the calculating the number of tankers that locate in Bangkok depot.

The study results obtained show that the optimal number of 10 wheelers that locate in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong is 63, 4, 0, 1, 12 and 0 respectively. And the number of semi-trailers that locate in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong is 0, 0, 2, 2, 0, and 12 respectively. The transportation cost is 368,454.46 bahts per day by estimating the diesel's price at 10.25 bahts per liter. So, The new transportation system can be more economic than the current system.

The analytical methods in this project can benefit the company for planning in transportation system with respect to the number of tankers.

ACKNOWLEDGEMENTS

I am indebted to the following people and organizations. Without them, this report would not have been possible.

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Special appreciation is due to my family and my friends for their fervent and continuous encouragement. They always exert a strong willpower for me to successfully complete this project.

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I. INTRODUCTION

1.1 General Background

Due to economic crisis a few years ago, many kinds of business try to find the several ways to develop their organization. The Oil Company is one business that faces the economic problems. Because of the big organization and having many competitors, the company has to control operating expense in order to keep the organization survive in this situation. The cost reduction of transportation department is one possible way to solve the problem. But it has to keep the quality of product and service to make customers satisfied.

The company has many depots distributed to all regions in Thailand. The biggest depot being located in Bangkok. There are two types of tankers which are used for delivery of oil product and they are 10-wheelers, and semi-trailers.

In the past, the tankers are operated at individual location and delivered product to customers around their depot's area. In the case of delivery within Bangkok, they are operated during night time follow the law of transportation and stopped working during daytime. In the case of delivery at upcountry, the tankers are operated during daytime and stopped working during night time. According to the transportation system in the present, the company lost unnecessary expenses of nonworking time. Moreover it shows that the number of tankers exceed the operation because they are not operated to gain the most benefit.

1.2 Statement of Problem

According to the transportation system in the present, it needs to be developed to reduce unnecessary cost and to use all existent tankers gain the most utilization. The new transportation system in the author's idea is determining the optimal number of tankers that should be operated both in Bangkok and upcountry as much as possible. There are constraints that have to be considered in order to follow this new system as follows:

(1) Ban Hour

The law of transportation is an important constraint that should be considered to deliver product to customers in Bangkok by tankers. The transportation law allows the tankers run during night time of working day and all time on holiday. Moreover, the limitation of running them will be different as follows:

(a) The 10 wheelers can run during 22:00 p.m. to 06:00 a.m. and all time on holiday all areas of Bangkok.

(b) The semi-trailers can run only during 22:00 p.m. to 05:00 a.m. in the area outside ring of Bangkok.

(2) The Loading Capacity

The company uses two types of tankers for delivery product to customers, which are 10-wheelers, and semi-trailers. One semi-trailer has double capacity of 10 wheeler. Moreover, the operation cost of a semi-trailer is also lower than a 10 wheeler because it can save time for delivery product to customers that require high volume.

(3) The Size of Distribution Area

The size of distribution area effects to determine the types of the tankers that should deliver products. Some distribution areas are small size so that semi-trailers can not access them. Although semi-trailers can save cost more than 10 wheelers, 10 wheelers have to be used to access these areas.

1.3 Objectives of the Study

This project concentrates on calculating methods in order to develop the transportation system. The objectives of the study are as follows:

(1) To reduce the transportation cost.

(2) To optimize number of 10-wheelers and semi-trailers that are used for delivering gasoline product to customers.

1.4 Scope and Limitation

This project focuses on delivering gasoline product to customers in Bangkok, Ayutthaya, Saraburi, Pathumtanee, Samutsongkhram, and Rayong by 10-wheelers and semi-trailers.

II. LITERATURE REVIEW

The objective of this research is to design the distribution system of oil product that reach the least cost of both inventory and transportation. This research determines the customers' requirement in term of deterministic that is the constant value. The researcher divided delivery into 2 types that are Direct Shipping and Peddling. In the case of direct shipping, the optimum quantity of transportation is provided by nonlinear programming technique that truck's capacity is determined as a constraint. In the case of peddling, the optimum quantity of transportation is full capacity of the truck. The objective function is cost minimization (Al-amin 1989).

This research is determining the route for delivery the several kinds of products which use different types of trucks. These trucks carry the goods from only one warehouse to many customers. The researcher develops iteration process to determine the most appropriate route. The obtained result is the number of truck and quantity of products per truck (Clarke and Wright 1964).

The objective of this research is to determine distribution model of different products from supplier to customer. The researcher determines the number of depots and location by using nonlinear programming mixed with integer programming techniques (Bookbinder and Reece 1988).

The objective of this research is to analyze the problems of vehicle routing. The constraint function is total distance of transportation per truck. There are two objective functions. One function is minimization of total distances of transportation. Another is minimization of the number of trucks (Li, David, and Desrochers 1992).

This research uses optimization model in order to reduce the cost of Transportation By Trailer On Flat Car (TOFC) of United Parcel Service Company which is a logistic company. The company can solve the problem of order scheduling by using integer linear programming (ILP) and minimum cost network flow program. The obtained result makes the company can save $4,000,000 per year (Dial 1991).

The objective of this research is to determine the optimum number of buses and trips that yield the least total cost, defined as the sum of Bangkok Mass Transit Authority's cost and the passenger's cost. The researcher studied in the case of zone 3 division 1 which consisted of 5 bus routes: route 25*, route 25, route 142, route 145*, and route 145, using linear programming technique and sensitivity analysis as analytical tools. She divided the study time into 2 periods that are peak and non-peak period. The objective function is minimization cost of the number and trips of bus. The constraint function are size and existing number of buses, number of buses during peak period and non-peak period, and the number of trips for each route. The sensitivity analysis is used for consideration of the result from linear programming model to analyze the change of coefficients value or parameters. The obtained result is the optimum number of bus for each route per day and the number of trip during peak period per bus per day and the number of trip during non-peak period per bus per day. The analytical methods and obtained results are guideline for solving the BMTS's loss and for planning with respect to the number of buses and trips for all available routes (พริ้มเพรา 2534).

According to the review of other research and techniques that relate to the problem in this project, there are several techniques and tools that can solve the problem in this project as follows:

2.1 Linear Programming (LP)

Linear Programming is a technique to solve the problem of allocating limited resources among competing activities as well as other problems having a similar mathematical formulation.

This method uses a mathematical model to describe the problem of concern. It involves the planning of activities to obtain an optimal result, i.e., a result that reaches the specified goal best (according to the mathematical model) among all feasible alternatives.

Render and Stair (1997) stated definition of linear programming that "it is a mathematical technique used to help management decide how to make the most effective use of an organization's resources".

Linear Programming is concerned with problems in which a linear objective function in terms of decision variables is to be optimized (i.e., either minimized or maximized) while a set of linear equations, inequalities, and sign restriction are imposed on the decision variables as requirements (Fang and Puthenpura 1993).

Linear Programming (LP) is a mathematical procedure for determining optimal allocation of scarce resources. LP is a procedure which has found practical application in almost all facets of business, from advertising to production planning, Transportation, distribution and aggregate production planning problems are the most typical objects of LP analysis (Schrage 1981).

2.1.1 History of Linear Programming (Fang and Puthenpura 1993)

The linear programming problem was first conceived by G.B. Dantzig around 1947 while he was working as a Mathematical Advisor to the United States Air Force Comptroller on developing a mechanized planning tool for a deployment, training, and logistical supply program. The work led to his 1948 publication, "Programming in a

Linear Structure." The name "linear programming" was coined by T.C. Koopmans and Dantzig in the summer of 1948, and an effective "simplex method" for solving linear programming problems was proposed by Dantzig in 1949. In the short period between 1947 and 1949, a major part of the foundation of linear programming was laid. As early as 1947, Koopmans began pointing out that linear programming provided an excellent framework for the analysis of classic economic theories.

Linear programming was not, however, born overnight. Prior to 1947, mathematicians had studied systems of linear inequalities, the core of the mathematical theory of linear programming. The investigation of such systems can be traced to Fourier's work in 1826. Since then, quite a few mathematicians have considered related subjects. In particular, the optimality conditions for functions with inequality constraints in the finite-dimensional case appeared in W. Karush's master's thesis in 1939, and various special cases of the fundamental duality theorem of linear programming were proved by others. Also, as early as 1939, L. V. Kantorovich pointed out the practical significance of a restricted class of linear programming models for production planning and proposed a rudimentary algorithm for their solution. Unfortunately, Kantorovich's work remained neglected in the U.S.S.R. and unknown elsewhere until long after linear programming had been well established by G.B. Dantzig and others.

Linear programming kept evolving in the 1950s and 1960s. The theory has been enriched and successful applications have been reported. In 1975, the topic came to public attention when the Royal Sweden Academy of Sciences awarded the Nobel Prize in economic science to L. V. Kantorobich and T.C. Koopmans "for their contributions to the theory of optimum allocation of resources." Yet another dramatic development in linear programming came to public attention in 1979: L.G. Khachian proved that the so-called “ellipsoid method” of N. Z. Shor, D. B. Yudin, and A. S. Nemirovskii, which differs radically from the simplex method, could outperform the simplex method in theory. Unlike the simplex method, which might take an exponential number of iterations to reach an optimal solution, the ellipsoid method finds an optimal solution of a linear programming problem in a polynomial-time bound. Newspapers around the world published reports of this result as if the new algorithm could solve the most complicated and large-scale resource allocation problems in no time. Unfortunately, the theoretic superiority of the ellipsoid method could not be realized in practical applications.

In 1984, a real breakthrough came from N. Karmarkar's “projective scaling algorithm: for linear programming. The new algorithm not only outperforms the simplex method in theory but also shows its enormous potential for solving very large-scale practical problems. Karmarkar's algorithm is again radically different form the simplex method-it approaches an optimal solution from the interior of the feasible domain. This interior-point approach has become the focal point of research interests in recent years. Various theoretic developments and real implementations have been reported, and further results are expected.

2.1.2 Components of Linear Programming Model (Turban and Meredith 1997)

The LP model consists of three components as follows:

(1) The Decision Variables

The decision variables in LP depend on the type of LP problem being considered. They can be the quantities of the resources to be allocated, or the number of units to be produced. The decision maker is searching for the value of unknown variables (usually denoted by x_1, x_2,...or x, y, and z) that will provide an optimal solution to the problem.

(2) The Objective Function

An LP Model attempts to optimize a single goal, written as a linear function. It attempts to find either the maximum level of a desired goal, such as total share of the market or total profit, or the minimum level of some undesirable outcome, such as total cost.

(3) The Constraints

The decision maker is searching for the values of the decision variables that will maximize (or minimize) the value of the objective function. Such a process is usually subject to several uncontrollable restrictions, requirements, or regulations that are called constraints. These constraints are expressed as linear inequalities and/or equations.

2.1.3 Standard Form of Linear Programming Model (Turban and Meredith 1997)

The general LP Problem can be presented in the following mathematical terms.

Let:

a_{ij} = The input-output coefficients

b_i = The capacities (right hand side)

c_j = The cost (profit) coefficients

x_j = The decision variables

Find a vector $(x_1,\dots,x_n)$ that minimizes (or maximizes) a linear objective function F(x) where:

$$F(x) = c_1x_1 + c_2x_2 + \cdots + c_jx_j + \cdots c_nx_n$$

Subject to the linear constraints:

$$\begin{array}{lllll} a_{11}x_1 & + a_{12}x_2 & + \cdots + a_{1n}x_n & \leq & b_1 \\ a_{21}x1 & + a_{22}x_2 & + \ldots + a_{2n}x_n & \leq & b_2 \\ \ldots & \ldots & \ldots & & \ldots \\ a_{i1}x_1 & + a_{i2}x_2 & + \cdots + a_{in}x_n & \leq & b_i \\ \ldots & \ldots & \ldots & & \ldots \\ a_{m1}x_1 & + a_{m2}x_2 & + \cdots + a_{m}x_n & \leq & b_m \end{array}$$

and the nonnegativity constraints:

$x_1 \geq 0, x_2 \geq 0,$

2.1.4 Assumptions of the Linear Programming Model (Fang and Puthenpura 1953)

In order to represent an optimization problem as a linear programming problem, implicitly you make the following assumptions:

(1) Proportionality assumption: For each decision variable x_j, for j =1,...,n, its contribution to the objective function z and to each:

$$\sum_{j=1}^{n} a_{ij}x_j = b_i, \qquad for \quad i = 1, \ldots, m,$$

constraint is directly proportional to its value. There are no economies of returns to scale or discounts at all.

(2) Additivity assumption: The contribution to the objective function or any technological constraint of any decision variable is independent of the values of other decision variables. There are no interaction or substitution

effects among the decision variables. The total contribution is the sum of the individual contributions of each decision variable.

(3) Divisibility assumption: Each decision variable is allowed to assume any fractional value.

(4) Certainty assumption: Each parameter (the cost coefficient c_j, the technological coefficient a_{ij} and the right handside coefficient b_i) is known with certainty. No probabilistic or stochastic element is involved in a linear programming problem.

2.2 Integer Linear Programming (ILP)

The Integer Linear Programming (ILP) model is a model that has constraints and an objective function identical to that formulated by linear programming. The only difference is that one or more of the decision variables has to take on an integer value in the final solution. This method is the extension of linear programming that solves problems requiring integer solution (Render and Stair 1997).

Integer linear programming can solve the problem of linear programming model so that an optimal integer solution is guaranteed. Because one assumption of linear programming is divisibility which requires that non-integer values be permissible for decision variables. In many practical problems, the decision variables actually make sense only if they have integer values for example, it is often necessary to assign people, machines, and vehicles to activities in integer quantities (Hiller and Gerald 1990).

There are three types of integer models as follows (Cook and Robert 1989):

(a) All Integer

All integer models require some or all of the decision variables to be integer. The pure-integer or all-integer model requires all variables to be integer. If all other relationships in the model are linear, the problem is called an integer linear program or ILP.

(b) Mixed-integer

Mixed-integer or MILP Models require some variables to be integer but allow the remaining variables to be continuous (noninteger).

(c) 0-1 integer models require all variables to assume a value of either 0 or 1.

2.3 Branch and Bound Method

The branch and bound method is an algorithm that can be used to solve all integer and mixed integer linear programs. It searches for an optimal solution by examining only a small part of the total number of possible solutions. This method is especially useful when enumeration becomes economically impractical or impossible because there are a large number of feasible solutions (Render and Stair 1997).

2.4 Lindo Program

LINDO is a good computer program for solving an LP requires a large number of calculations. The acronym stands for Linear, Interactive, and Discrete Optimizer. Its main purpose of LINDO is to allow a user to quickly input and LP formulation; solve it; asses the correctness or appropriateness of the formulation based on the solution and then quickly make minor modifications to the formulation and repeat the process (Schrage 1984).

2.5 QM for Windows

QM for windows is one software package that allows you to solve many of the quantitative analysis problems. This software has been written for the windows operating system for IBM and compatible personal computers. QM for windows has menu selection at the top of the screen like other window applications so it is the most user-friendly software (Render and Stair 1997).

III. TRANSPORTATION POLICIES

The company that the author studied is a manufacturer and transportation oil products to customers all over Thailand. There are three types of distribution channels oil products are delivered to customers as follows:

(1) Wholesale

This type is distribution the oil products which have the total volume is not less than 10,000 liters per order. The customers of wholesale type may be some customers come into the company in order to load the product by themselves or some customers who own petrol station which the company has duty to deliver the product to them.

(2) Retail

This type is distribution the oil product to petrol stations and consumers directly. The difference of retail and wholesale type are price condition and term of payment.

(3) Commercial

This type is distribution the oil product to industries directly. The company has duty to deliver product to them or some customers can load the product at the company's depot.

3.1 The Operation Process of Oil Products Distribution

Figure 3.1 shows the operation process of distribution the oil product to the customers.

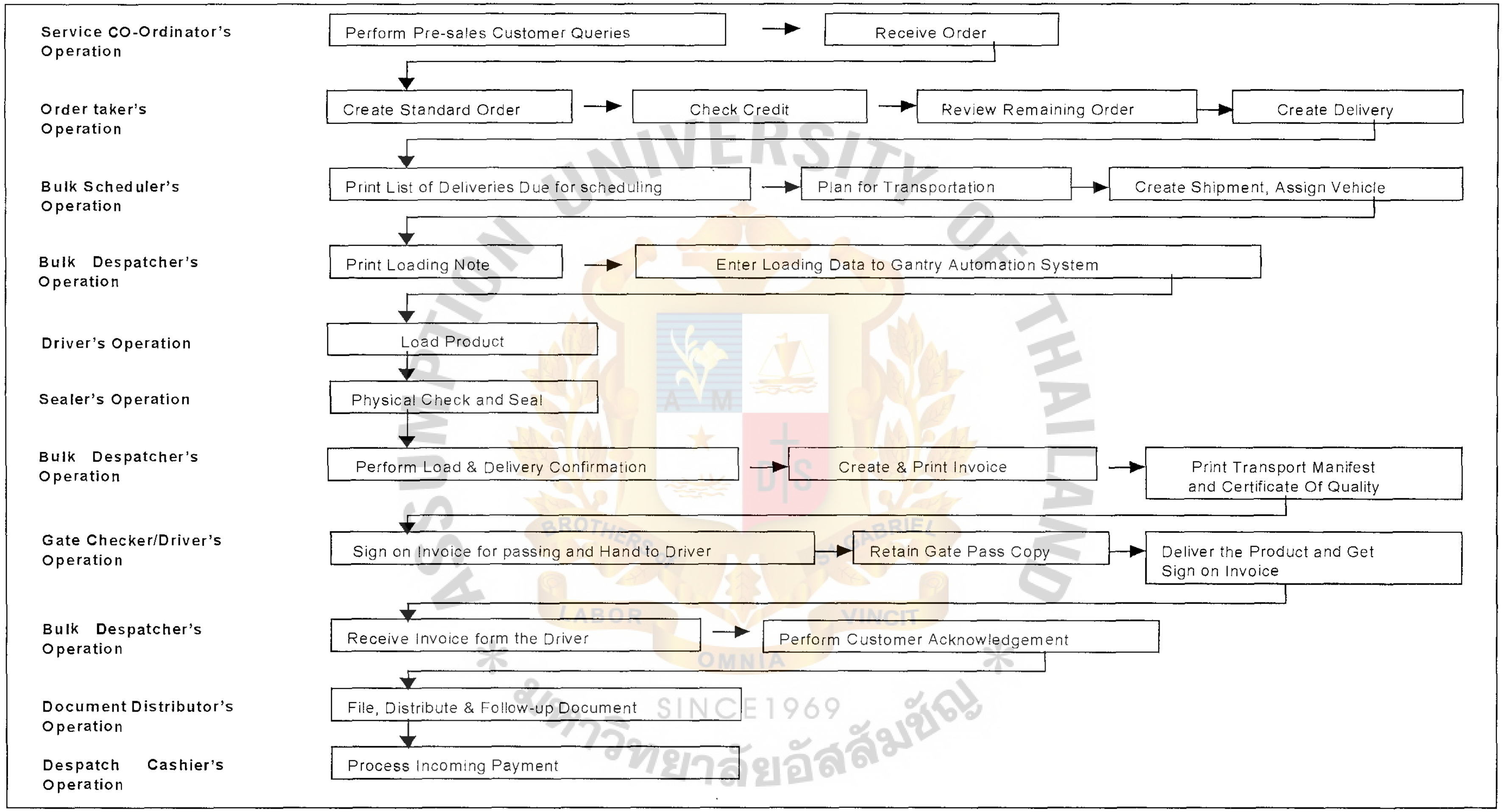


Figure 3.1. The Operation Process of Distribution the Oil Product.

3.2 The Limitation of Transportation Oil Product

To determine the delivery schedule of oil product depend on the officers' decision which need to have skill and knowledge in order to allocate the order scheduling efficiently. One thing that they must consider is limitation that relates to transportation as follows:

(1) The company's policies state that customers should order 15,000 liters or 30,000 liters per shipment. If some customers order product less than 15,000 liters, the minimum charge rate will be 15,000 liters per delivery.

(2) There are 2 types of tankers that are operated by company and contractor. Each tankers has different compartments, so their loading capacity is also different as follows:

(a) 10 wheelers

The 10 wheeler's loading capacity is 15,000 liters. It has 5 compartments, which have capacity 3,000 liters per compartment as Figure 3.2.

(b) Semi-trailers

The semi-trailer's loading capacity is 30,000 liters. It can be separated to 2 types base on the characteristic of compartment as follows:

(1) Semi-trailer has 10 compartments in which each compartment has capacity 3,000 liters as Figure 3.3.

(2) Semi-trailer has 7 compartments that have different capacity as Figure 3.4.

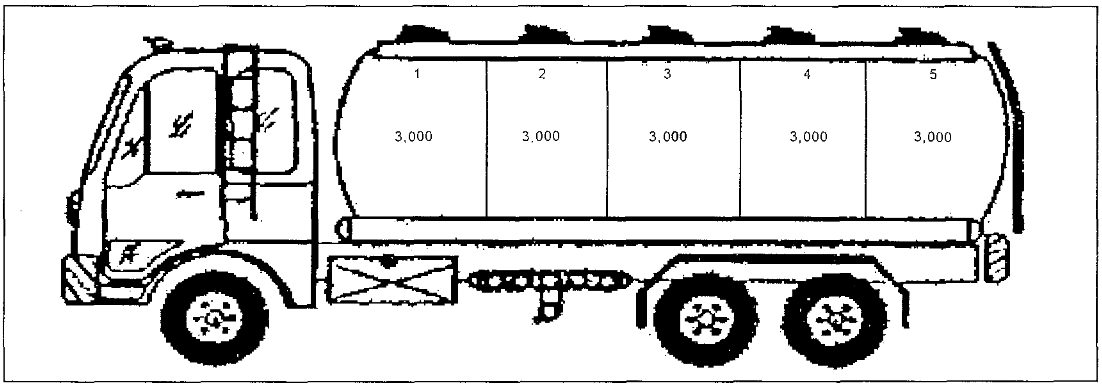


Figure 3.2. The 10 Wheeler.

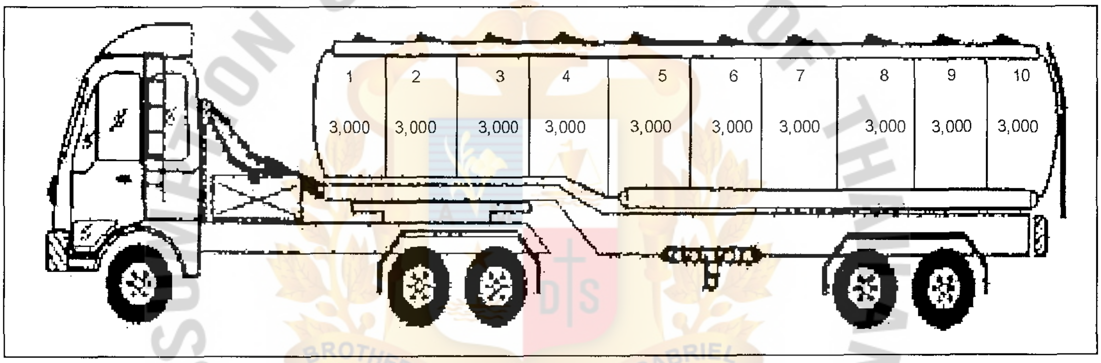


Figure 3.3. The Semi-trailer with 10 Compartments.

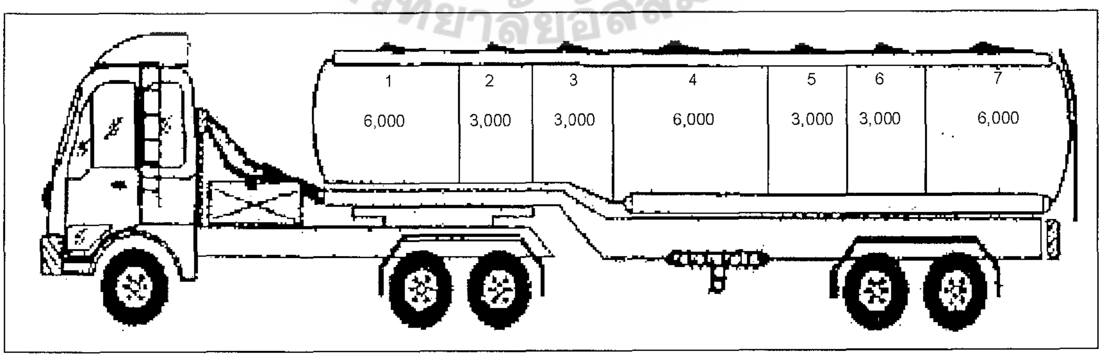


Figure 3.4. The Semi-trailer with 7 Compartments.

(3) The Service Agreement

The company's policies state the time of receiving order and delivery product as in Table 3.1.

Table 3.1. The Service Agreement.

	Cut Off Time	Oil Retail (OR)	Oil Commercial(OC)
Bangkok	15.00	06.00	06.00
Upcountry Depot	17.00	18.00	17.00

Remark: Cut off Time means the finishing time that company receives order from customer for each day.

The description in the Table 3.1 is as follows:

(a) In case of Bangkok, both Oil retail type and Oil Commercial type, If customers order product before 15.00 p.m., they will receive product before 06.00 a.m. on next day.

(b) In case of Upcountry depot and Oil Retail type, If customers order product before 17.00 p.m., they will receive product before 18.00 p.m. on next day.

(c) In case of Upcountry depot and Oil Commercial type, If customers order product before 17.00 p.m., they will receive product before 17.00 p.m. on next day.

(d) Ban Zone and Ban Hour (สำนักงานคณะกรรมการจัดระบบการจราจรทางบก 2542)

The legislation limit the area or ban zone and time period or ban hour of running each type of the tankers in Bangkok. Ban zone is the region that the tankers are not allowed to run which can be separated into two boundaries: inner boundary and outer boundary. Inner boundary is the center area of Bangkok that has diameter approximately 10 kilometers. Outer boundary is the remainder area of inner boundary. The time limitation of running the tankers will be different depend on the type of them as follows:

(1) 10 wheelers are not allowed to run during 06.00 am to 22.00 p.m. everyday except holiday. In another word, 10 wheelers can run during 22.00 p.m. to 06.00 a.m. and all time on holiday all area of Bangkok.

(2) Semi-trailers are not allowed to run during 05:00 a.m. to 22:00 p.m. In another word, the semi-trailers can run during 22.00 p.m. to 05.00 am around only area outer ring of Bangkok.

You can see more detail of ban zone and ban hour from Appendix A and B.

IV. RESEARCH METHODOLOGY

In this chapter, the author divides the study into 3 parts. The first part is the planning and designing of the tankers' route model. The second part is the formulation of linear programming model to compute the optimal number of tankers in upcountry depot in order to minimize the transportation cost. The third part is calculating the number of tankers in Bangkok depot.

4.1 The Tankers' Route Model

This section is the planning and designing the route that the tankers use for delivering the oil product to customers located both in Bangkok and upcountry following the new transportation system. The objective of the route model is to estimate the number of trips or orders per day that one 10 wheeler or one semi-trailer can operate. There are several factors effecting in planning the route in order to utilize the tankers as much as possible such as the operation time, the transportation law, and distance. This project will focus on the transportation's route between Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong. The author assumes BK, PT, AU, SB, SK, and RY represent to the depots located in these provinces respectively.

4.1.1 The Related Factor of Planning the Route Model

The following factors that the company must consider for planning the route model of tankers as the new transportation system is shown as below:

(1) The Depot's Operation Time

The depot's operation time means the working time of each depot. The upcountry depots open at 7:30 a.m. and close at 16:30 p.m. But the Bangkok depot opens all time.

(2) The Tanker's Operation Time

The tanker's operation time means the time spent in the distribution process. The tanker's operation time consists of:

(a) The waiting or queuing time.

(b) The loading time of oil product.

(c) The waiting time to leave the depot.

(d) The driving time from depot to destination or customer's site.

(e) The unloading time of oil product at destination or customer's site.

(f) The driving time back from destination or customer's site to depot.

The average time that is obtained from the company can be shown in Tables 4.1 and 4.2.

Table 4.1. The Average of Operation's Time in the Distribution Process of 10 Wheeler.

Time (minutes.) \ Depot	BK	PT	AU	SB	SK	RY
Waiting or queuing	13	19	11	21	23	56
Loading	17	40	21	33	30	30
Waiting to leave depot	16	22	18	36	41	32
Total time before driving to customer's site	**46**	**81**	**50**	**90**	**94**	**118**
Driving to customer's site	39	82	63	137	112	165
Unloading	40	69	64	66	65	66
Driving to depot	39	47	40	76	122	182
Total time/ trip	**164**	**279**	**217**	**369**	**393**	**531**

Table 4.2. The Average of Operation's Time in the Distribution Process of Semi-Trailer.

Time (minutes.) \ Depot	BK	PT	AU	SB	SK	RY
Waiting or queuing	13	19	11	21	23	56
Loading	25	59	31	49	45	45
Waiting to leave depot	16	22	18	36	41	32
Total time before driving to customer's site	**54**	**100**	**60**	**106**	**109**	**133**
Driving to customer's site	39	82	63	137	112	165
Unloading	60	103	96	99	97	99
Driving to depot	39	47	40	76	122	182
Total time/ trip	**192**	**332**	**259**	**418**	**440**	**579**

From Tables 4.1 and 4.2 the total time before driving to customer's site and the total time per trip are calculated by

Total time before driving to customer's site (minutes)

= Waiting or queuing (minutes)+

Loading (minutes)+

Waiting to leave depot (minutes)

The total time per trip (minutes)

= Total time before driving to customer's site (minutes)+

Driving to customer's site (minutes)+

Unloading (minutes)+

Driving to depot (minutes)

(3) Distance from Upcountry Depots to Bangkok Depot

The distance from each upcountry depot to Bangkok depot is a factor that has to be considered in order to estimate the time of running the tankers. The data is obtained from company that can be shown in Table 4.3.

Table 4.3. The Distance from Upcountry Depots to Bangkok Depot.

Route	Distance(km.)
PT ↔ BK	46
AU ↔ BK	60
SB ↔ BK	115
SK ↔ BK	87
RY ↔ BK	176

(4) The Maximum Speed of Running the Tankers

The transportation law states the maximum speed of running 10 wheeler is 80 kilometers per hour and semi-trailer is 60 kilometers per hour.

(5) The Company's Service Agreement to Customer

The company's service agreement to customer relate to the time of delivery the oil product to customer. The more detail of service agreement is described in Chapter 3.

(6) Ban Hour and Ban Zone

Ban hour and Ban zone are the role of running the tankers that relates to designing the transportation's route in Bangkok. The description of ban hour and ban zone is described in Chapter 3 and Appendix A that can be concluded as follows:

(a) The 10 wheeler can run during 22.00 p.m. to 06.00 a.m.

(b) The semi-trailer can run during 22.00 p.m. to 05.00 a.m.

4.1.2 The Tanker's Route Model Planning

This section is planning and designing the transportation's route of one tanker. Because of the difference of tanker's operation in each type, the model can be divided into 2 types that are the model of a 10 wheeler and the model of a semi-trailer. The route model in this project is designed by consideration of the operation time. So, it does not indicate the route exactly. Because you can not determine which customers order the oil product each day. However, this model still must use the skilled persons in order to allocate the tankers to deliver the oil product to customers each day.

Due to the difference of the depot's operation time, the tankers' operation time and the other factors that are described in section 4.1. So, the route model of the tanker will be different in each depot. The symbols that are used in the route model are shown in Figure 4.1.

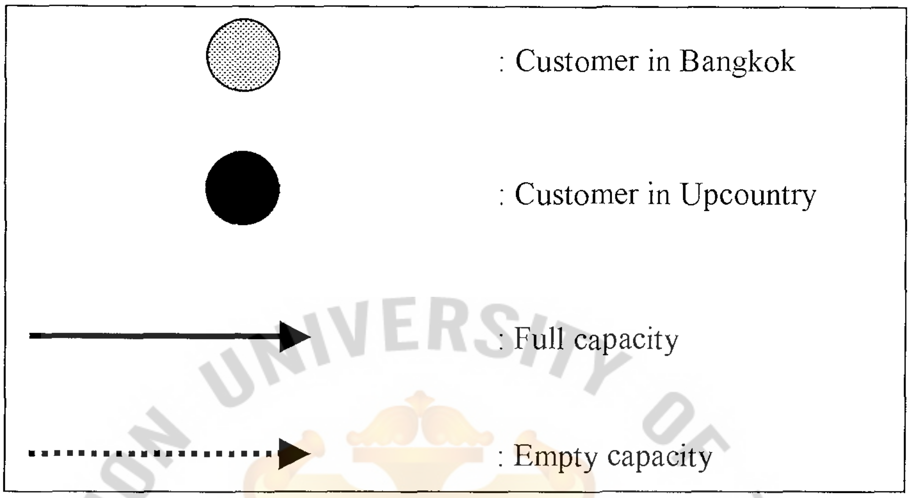


Figure 4.1. The Symbols Used in the Tanker's Route Model.

The procedures of designing the tanker's route are as follows:

(1) The Route between Bangkok to Pathumtanee (BK ↔ PT)

(a) The Route Model of 10 Wheeler

Due to ban hour and ban zone that allow the 10 wheeler runs during 22:00 p.m.- 06:00 a.m., the first point will be started at 22:00 p.m. that 10 wheeler can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 45 minutes. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The 10 wheeler spends 45 minutes for arriving Bangkok depot, so the time will be 22:45 p.m.

(3) Spends 46 minutes before driving to the customer's site as in Table 4.1, so the time will be 23:31 p.m.

(4) Spends 39 minutes for driving to customer's site, so the time will be 0:10 a.m.

(5) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 0:50 a.m.

(6) Spends 39 minutes for driving to Bangkok depot, so the time will be 1:29 a.m.

(7) Spends 46 minutes before driving to the customer's site, so the time will be 2:15 a.m.

(8) Spends 39 minutes for driving to the customer's site, so the time will be 2:54 a.m.

(9) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 3:34 a.m.

(10) Spends 39 minutes for driving back Bangkok depot, so the time will be 4:13 a.m.

(11) Spend 46 minutes before driving to the customer's site, so the time will be 4:59 a.m.

At 4:59 a.m., the 10 wheeler will be operated to deliver product to customer in Pathumtanee because the remainder time is only 1 hour that is not enough to be operated to deliver the oil product to a customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between

Pathumtanee and Bangkok is approximately 46 kilometers. Moreover, the transportation law allows the maximum speed of running the 10 wheeler is 80 km./hr. Therefore, the 10 wheeler can arrive customer at 7:00 a.m. It will be then operated by spending the operation time of Pathumtanee depot as Table 4.1 as follows:

(1) Spends 69 minutes for unloading oil product at the customer's site, so the time will be 8:09 a.m.

(2) Spends 47 minutes for driving back Pathumtanee depot, so the time will be 8:56 a.m.

(3) Spends 81 minutes before driving to the customer's site, so the time will be 10:17 a.m.

(4) Spends 82 minutes for driving to the customer's site, so the time will be 11:39 a.m.

(5) Spends 69 minutes for unloading the oil product at the customer's site, so the time will be 12:48 p.m.

(6) Spends 47 minutes for driving to Pathumtanee depot, so the time will be 13:35 p.m.

(7) Spends 81 minutes before driving to the customer's site, so the time will be 14:56 a.m.

(8) Spends 82 minutes for driving to the customer's site, so the time will be 16:18 a.m.

(9) Spends 69 minutes for unloading oil product at the customer's site, so the time will be 17:27 p.m.

At 17:27 p.m., the 10 wheeler will finish unloading the oil product at customer's site in Pathumtanee. Since the depot closed at

16:30 p.m. and the remainder timer is 4 hours and 33 minutes. So, the 10 wheeler can leave Pathumtanee and prepare to enter Bangkok at 22:00 p.m. From the description and procedures that are described above, the route model can be created as Figure 4.2.

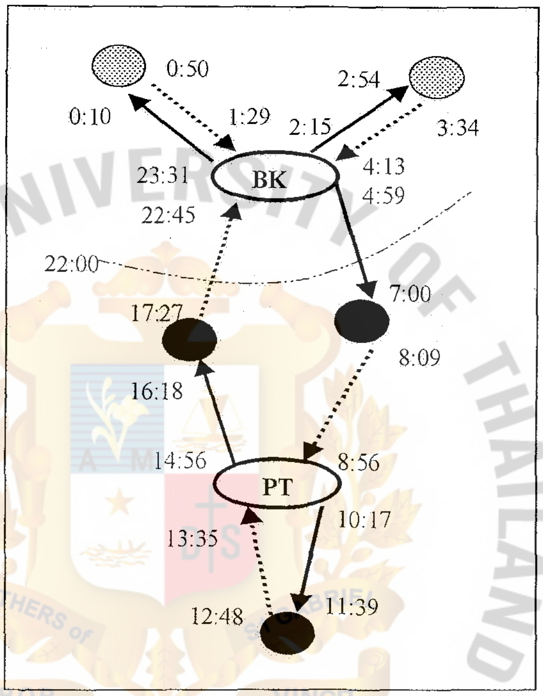


Figure 4.2. The Route Model between Bangkok and Pathumtanee of One 10 Wheeler.

(b) The Route Model of Semi-Trailer

Due to ban hour and ban zone that allow the semi-trailer run during 22:00 p.m. – 05:00 a.m., the first point will be started at 22:00 p.m. when the semi-trailer can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 60 minutes or 1 hour. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The semi-trailer spends 60 minutes for arriving Bangkok depot, so the time will be 23:00 p.m.

(3) Spends 54 minutes before driving to the customer's site as Table 4.2, so the time will be 23:54 p.m.

(4) Spends 39 minutes for driving to the customer's site, so the time will be 0:33 a.m.

(5) Spends 60 minutes for unloading the oil product at the customer's site, so the time will be 1:33 a.m.

(6) Spends 39 minutes for driving back Bangkok depot, so the time will be 2:12 a.m.

(7) Spends 54 minutes before driving to the customer's site, so the time will be 3:06 a.m.

At 3:06 a.m., the semi-trailer will be operated to deliver product to customer in Pathumtanee. Because the remainder time is only 1 hour and 54 minutes it is not enough to be operated to deliver the oil product to customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Pathumtanee and Bangkok is approximately 46 kilometers. Moreover, the transportation law allows the maximum speed of running the semi-trailer is 60 km./hr. Therefore, the semi-trailer can arrive customer at 7:00 a.m. It will be then operated by spending the operation time of Pathumtanee depot as follows:

(1) Spends 103 minutes for unloading oil product at the customer's site, so the time will be 8:43 a.m.

(2) Spends 47 minutes for driving to Pathumtanee depot, so the time will be 9:30 a.m.

(3) Spends 100 minutes before driving to the customer's site, so the time will be 11:10 a.m.

(4) Spends 82 minutes for driving to the customer's site, so the time will be 12:32 a.m.

(5) Spends 103 minutes for unloading the oil product at the customer's site, so the time will be 14:15 p.m.

At 14:15 p.m., the semi-trailer will finish unloading the oil product at customer's site in Pathumtanee. Since the depot is closed at 16:30 p.m. and the remainder time is 7 hours and 45 minutes. So, the semi-trailer can leave Pathumtanee in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, the route model can be created as Figure 4.3.

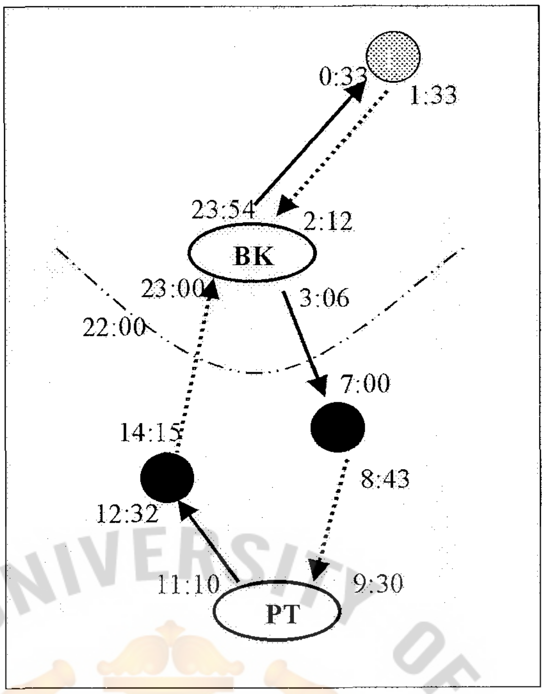


Figure 4.3. The Route Model between Bangkok and Pathumtanee of One Semi-Trailer.

(2) The Route between Bangkok to Ayutthaya (BK ↔ AU)

(a) The Route Model of 10 Wheeler

Due to ban hour and ban zone that allow the 10 wheeler run during 22:00 p.m.- 06:00 a.m., the first point will be started at 22:00 p.m. that 10 wheeler can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 45 minutes. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The 10 wheeler spends 45 minutes for arriving Bangkok depot, so the time will be 22:45 p.m.

(3) Spends 46 minutes before driving to the customer's site as Table 4.1, so the time will be 23:31 p.m.

(4) Spends 39 minutes for driving to customer's site, so the time will be 0:10 a.m.

(5) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 0:50 a.m.

(6) Spends 39 minutes for driving back Bangkok depot, so the time will be 1:29 a.m.

(7) Spends 46 minutes before driving to the customer's site, so the time will be 2:15 a.m.

(8) Spends 39 minutes for driving to the customer's site, so the time will be 2:54 a.m.

(9) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 3:34 a.m.

(10) Spend 39 minutes for driving back Bangkok depot, so the time will be 4:13 a.m.

(11) Spend 46 minutes before driving to the customer's site, so the time will be 4:59 a.m.

At 4:59 a.m., the 10 wheeler will be operated to deliver the product to the customer in Ayutthaya because the remainder time is only 1 hour that is not enough to be operated to deliver the oil product to the customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Ayutthaya and Bangkok is approximately 60 kilometers. Moreover, the transportation law allows the maximum speed of running the 10 wheeler is 80 km./hr. Therefore, the 10 wheeler can arrive customer at 7:00 a.m. It will be then operated by spending the operation time of Ayutthaya depot as Table 4.1 as follows:

(1) Spends 64 minutes for unloading oil product at the customer's site, so the time will be 8:04 a.m.

(2) Spends 40 minutes for driving to Ayutthaya depot, so the time will be 8:44 a.m.

(3) Spends 50 minutes before driving to the customer's site, so the time will be 9:34 a.m.

(4) Spends 63 minutes for driving to the customer's site, so the time will be 10:37 a.m.

(5) Spends 64 minutes for unloading the oil product at the customer's site, so the time will be 11:41 a.m.

(6) Spends 40 minutes for driving back Ayutthaya depot, so the time will be 12:21 p.m.

(7) Spends 50 minutes before driving to the customer's site, so the time will be 13:11 p.m.

(8) Spends 63 minutes for driving to customer's site, so the time will be 14:14 p.m.

(9) Spends 64 minutes for unloading oil product at the customer's site, so the time will be 15:18 p.m.

At 15:18 p.m., the 10 wheeler will finish unloading the oil product to customer in Ayutthaya. Since the depot is closed at 16:30 p.m. and the remainder time is 6 hours and 42 minutes. So, the semi-trailer can leave Ayutthaya in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.4.

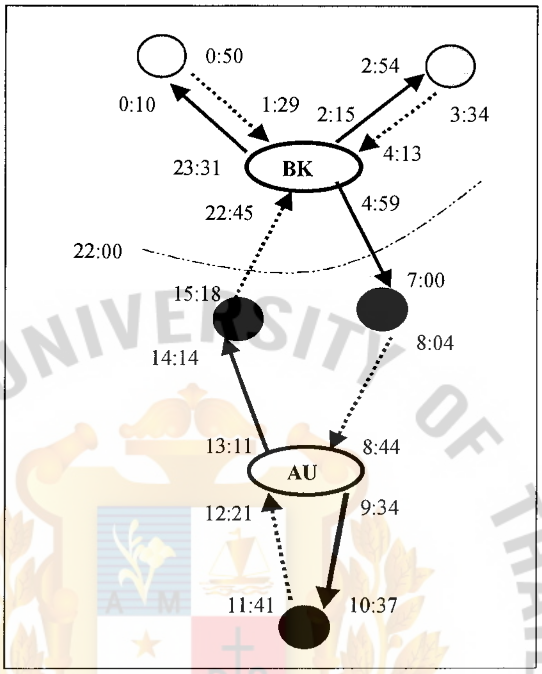


Figure 4.4. The Route Model between Bangkok and Ayutthaya of One 10 Wheeler.

(b) The Route Model of Semi-Trailer

Due to ban hour and ban zone that allow the semi-trailer run during 22:00 p.m. – 05:00 a.m., the first point will be started at 22:00 p.m. which the semi-trailer can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 60 minutes or 1 hour. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The semi-trailer spends 60 minutes for arriving Bangkok depot, so the time will be 23:00 p.m.

(3) Spends 54 minutes before driving to the customer's site as Table 4.2, so the time will be 23:54 p.m.

(4) Spends 39 minutes for driving to the customer's site, so the time will be 0:33 a.m.

(5) Spends 60 minutes for unloading the oil product at the customer's site, so the time will be 1:33 a.m.

(6) Spends 39 minutes for driving to Bangkok depot, so the time will be 2:12 a.m.

(7) Spends 54 minutes before driving to the customer's site, so the time will be 3:06 a.m.

At 3:06 a.m., the semi-trailer will be operated to deliver the product to the customer in Ayutthaya. Because the remainder time is only 1 hour and 54 minutes that is not enough to be operated to deliver the oil product to the customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Ayutthaya and Bangkok is approximately 60 kilometers. Moreover, the transportation law allows the maximum speed of running the semi-trailer is 60 km./hr. Therefore, the semi-trailer can arrive the customer site at 7:00 a.m. It will then be operated by spending the operation time of Ayutthaya depot as follows:

(1) Spends 96 minutes for unloading oil product at the customer's site, so the time will be 8:36 a.m.

(2) Spends 40 minutes for driving back Ayutthaya depot, so the time will be 9:16 a.m.

(3) Spends 60 minutes before driving to the customer's site, so the time will be 10:16 a.m.

(4) Spends 63 minutes for driving to the customer's site, so the time will be 11:19 a.m.

(5) Spends 96 minutes for unloading the oil product at the customer's site, so the time will be 12:55 p.m.

(6) Spends 40 minutes for driving to Ayutthaya depot, so the time will be 13:35 p.m.

(7) Spends 60 minutes before driving to the customer's site, so the time will be 14:35 p.m.

(8) Spends 63 minutes for driving to the customer's site, so the time will be 15:38 p.m.

(9) Spends 96 minutes for unloading the oil product at the customer's site, so the time will be 17:14 p.m.

At 17:14 p.m., the semi-trailer will finish unloading the oil product at the customer's site in Ayutthaya. Since the depot is closed at 16:30 p.m. and the remainder time is 4 hours and 46 minutes. So, the semi-trailer can leave Ayutthaya in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.5.

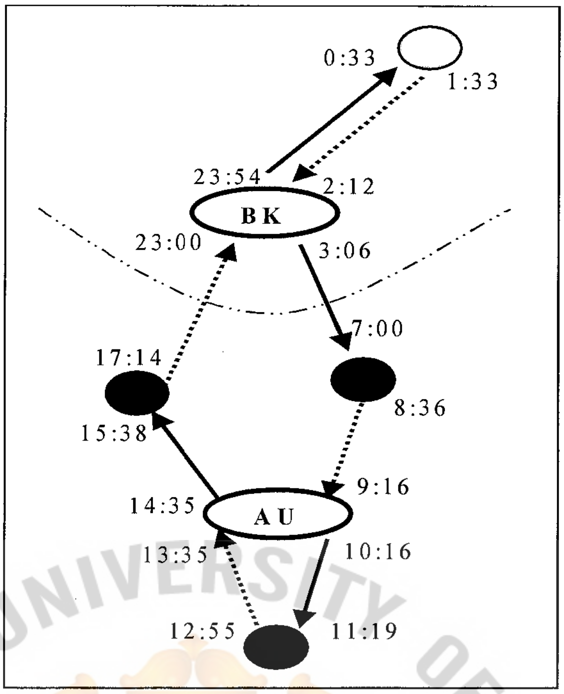


Figure 4.5. The Route Model between Bangkok and Ayutthaya of One Semi-Trailer.

(3) The Route between Bangkok to Saraburi (BK ↔ SB)

(a) The Route Model of 10 Wheeler

Due to ban hour and ban zone that allow the 10 wheeler run during 22:00 p.m.- 06:00 a.m., the first point will be started at 22:00 p.m. that 10 wheeler can enter Bangkok. The obtained data from the company indicates that the time for arriving Bangkok depot is about 45 minutes. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The 10 wheeler spends 45 minutes for arriving Bangkok depot, so the time will be 22:45 p.m.

(3) Spends 46 minutes before driving to the customer's site as Table 4.1, so the time will be 23:31 p.m.

(4) Spends 39 minutes for driving to customer's site, so the time will be 0:10 a.m.

(5) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 0:50 a.m.

(6) Spends 39 minutes for driving back Bangkok depot, so the time will be 1:29 a.m.

(7) Spends 46 minutes before driving to the customer's site, so the time will be 2:15 a.m.

(8) Spends 39 minutes for driving to the customer's site, so the time will be 2:54 a.m.

(9) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 3:34 a.m.

(10) Spend 39 minutes for driving back Bangkok depot, so the time will be 4:13 a.m.

(11) Spend 46 minutes before driving to the customer's site, so the time will be 4:59 a.m.

At 4:59 a.m., the 10 wheeler will be operated to deliver the product to the customer in Saraburi because the remainder time is only 1 hour that is not enough to be operated to deliver the oil product to the customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Saraburi and Bangkok is approximately 115 kilometers. Moreover, the transportation law allows the maximum speed of running the 10 wheeler is 80 km./hr. Therefore, the 10 wheeler can arrive the customer site at 7:00 a.m. It will be then operated by spending the operation time at Saraburi depot as Table 4.1 as follows:

(1) Spends 66 minutes for unloading oil product at the customer's site, so the time will be 8:06 a.m.

(2) Spends 76 minutes for driving to Saraburi depot, so the time will be 8:22 a.m.

(3) Spends 90 minutes before driving to the customer's site, so the time will be 10:52 a.m.

(4) Spends 137 minutes for driving to the customer's site, so the time will be 13:09 p.m.

(5) Spends 66 minutes for unloading the oil product at the customer's site, so the time will be 14:15 p.m.

At 14:15 p.m., the 10 wheeler will finish unloading the oil product at the customer' site in Saraburi. Since the depot is closed at 16:30 p.m. and the remainder time is 7 hours and 45 minutes. So, the 10 wheeler can leave Saraburi in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.6.

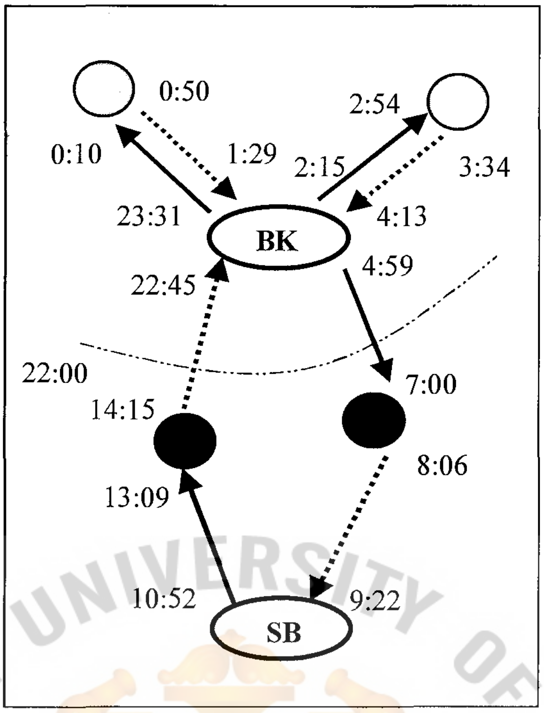


Figure 4.6. The Route Model between Bangkok and Saraburi of One 10 Wheeler.

(b) The Route Model of Semi-Trailer

Due to ban hour and ban zone that allow the semi-trailer run during 22:00 p.m. – 05:00 a.m., the first point will be started at 22:00 p.m.which the semi-trailer can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 60 minutes or 1 hour. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The semi-trailer spends 60 minutes for arriving Bangkok depot, so the time will be 23:00 p.m.

(3) Spends 54 minutes before driving to the customer's site as Table 4.2, so the time will be 23:54 p.m.

(4) Spends 39 minutes for driving to the customer's site, so the time will be 0:33 a.m.

(5) Spends 60 minutes for unloading the oil product at the customer's site, so the time will be 1:33 a.m.

(6) Spends 39 minutes for driving to Bangkok depot, so the time will be 2:12 a.m.

(7) Spends 54 minutes before driving to the customer's site, so the time will be 3:06 a.m.

At 3:06 a.m., the semi-trailer will be operated to deliver product to customer in Saraburi. Because the remainder time is only 1 hour and 54 minutes that is not enough to be operated to deliver the oil product to customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Saraburi and Bangkok is approximately 115 kilometers. Moreover, the transportation law allows the maximum speed of running the semi-trailer is 60 km./hr. Therefore, the semi-trailer can arrive customer at 7:00 a.m. It will be then operated by spending the operation time of Saraburi depot as follows:

(1) Spends 99 minutes for unloading oil product at the customer's site, so the time will be 8:39 a.m.

(2) Spends 76 minutes for driving back Saraburi depot, so the time will be 9:55 a.m.

(3) Spends 106 minutes before driving to the customer' site, so the time will be 11:41 a.m.

(4) Spends 137 minutes for driving to the customer's site, so the time will be 13:58 p.m.

(5) Spends 99 minutes for unloading the oil product at the customer's site, so the time will be 15:37 p.m.

At 15:37 p.m., the semi-trailer will finish unloading the oil product at the customer's site in Saraburi. Since the depot is closed at 16:30 p.m. and the remainder time is 6 hours and 23 minutes. So, the semi-trailer can leave Saraburi in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.7.

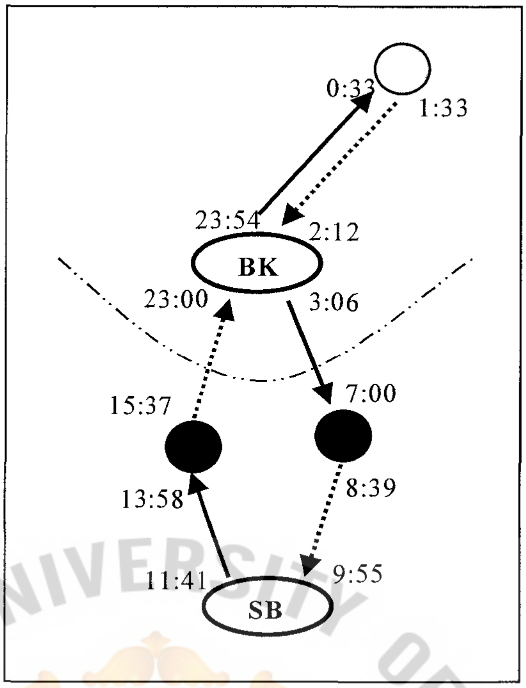


Figure 4.7. The Route Model between Bangkok and Saraburi of One Semi-Trailer.

(4) The Route between Bangkok to Samutsongkhram (BK ↔ SK)

(a) The Route Model of 10 Wheeler

Due to ban hour and ban zone that allow the 10 wheeler run during 22:00 p.m.- 06:00 a.m., the first point will be started at 22:00 p.m. that 10 wheeler can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 45 minutes. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The 10 wheeler spends 45 minutes for arriving Bangkok depot, so the time will be 22:45 p.m.

(3) Spends 46 minutes before driving to the customer's site as Table 4.1, so the time will be 23:31 p.m.

(4) Spends 39 minutes for driving to customer's site, so the time will be 0:10 a.m.

(5) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 0:50 a.m.

(6) Spends 39 minutes for driving to Bangkok depot, so the time will be 1:29 a.m.

(7) Spends 46 minutes before driving to the customer's site, so the time will be 2:15 a.m.

(8) Spends 39 minutes for driving to the customer's site, so the time will be 2:54 a.m.

(9) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 3:34 a.m.

(10) Spend 39 minutes for driving to Bangkok depot, so the time will be 4:13 a.m.

(11) Spend 46 minutes before driving to the customer's site, so the time will be 4:59 a.m.

At 4:59 a.m., the 10 wheeler will be operated to deliver product to customer in Samutsongkhram because the remainder time is only 1 hour that is not enough to be operated to deliver the oil product to customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. which the distance between Samutsongkhram and Bangkok is approximately 87 kilometers. Moreover, the transportation law allows the maximum speed of running the 10 wheeler is 80 km./hr. Therefore, the 10 wheeler can arrive customer at 7:00 a.m. It will be then operated by spending the operation time of Samutsongkhram depot as Table 4.1 as follows:

(1) Spends 65 minutes for unloading oil product at the customer's site, so the time will be 8:05 a.m.

(2) Spends 122 minutes for driving to Samutsongkhram depot, so the time will be 10:07 a.m.

(3) Spends 94 minutes before driving to the customer's site, so the time will be 11:41 a.m.

(4) Spends 112 minutes for driving to the customer's site, so the time will be 13:33 p.m.

(5) Spends 65 minutes for unloading the oil product at the customer's site, so the time will be 14:38 p.m.

At 14:38 p.m., the 10 wheeler will finish unloading the oil product at the customer's site in Samutsongkhram. Since the depot is closed at 16:30 p.m. and the remainder time is 7 hours and 22 minutes. So, the 10 wheeler can leave Samutsongkhram in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.8.

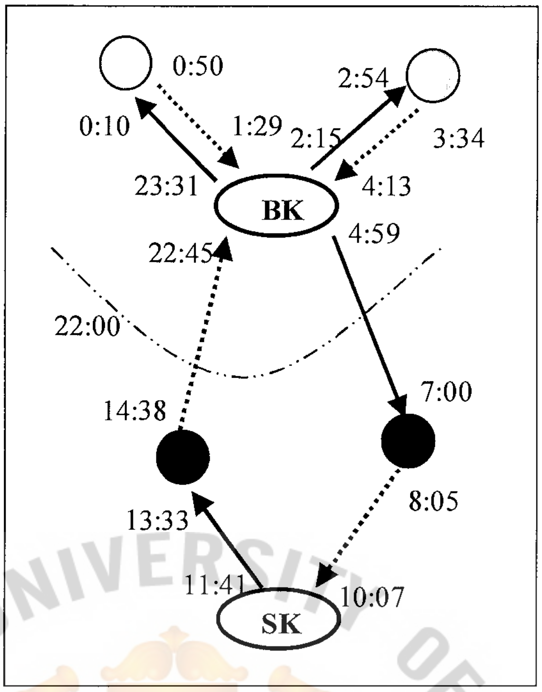


Figure 4.8. The Route Model between Bangkok and Samutsongkhram of One 10 Wheeler.

(b) The Route Model of Semi-Trailer

Due to ban hour and ban zone that allow the semi-trailer run during 22:00 p.m. – 05:00 a.m., the first point will be started at 22:00 p.m.which the semi-trailer can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 60 minutes or 1 hour. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The semi-trailer spends 60 minutes for arriving Bangkok depot, so the time will be 23:00 p.m.

(3) Spends 54 minutes before driving to the customer's site as Table 4.2, so the time will be 23:54 p.m.

(4) Spends 39 minutes for driving to the customer's site, so the time will be 0:33 a.m.

(5) Spends 60 minutes for unloading the oil product at the customer's site, so the time will be 1:33 a.m.

(6) Spends 39 minutes for driving to Bangkok depot, so the time will be 2:12 a.m.

(7) Spends 54 minutes before driving to the customer's site, so the time will be 3:06 a.m.

At 3:06 a.m., the semi-trailer will be operated to deliver product to customer in Samutsongkhram. Because the remainder time is only 1 hour and 54 minutes that is not enough to be operated to deliver the oil product to customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Samutsongkhram and Bangkok is approximately 87 kilometers. Moreover, the transportation law allows the maximum speed of running the semi-trailer is 60 km./hr. Therefore, the semi-trailer can arrive customer at 7:00 a.m. It will be then operated by spending the operation time of Samutsongkhram depot as follows:

(1) Spends 97 minutes for unloading oil product at the customer's site, so the time will be 8:37 a.m.

(2) Spends 122 minutes for driving back Samutsongkhram depot, so the time will be 10:39 a.m.

(3) Spends 109 minutes before driving to the customer's site, so the time will be 12:28 p.m.

(4) Spends 112 minutes for driving to the customer's site, so the time will be 14:20 p.m.

(5) Spends 97 minutes for unloading the oil product at the customer's site, so the time will be 15:57 p.m.

At 15:57 p.m., the semi-trailer will finish unloading the oil product at customer's site in Samutsongkhram. Since the depot is closed at 16:30 p.m. and the remainder time is 6 hours and 3 minutes. So, the semi-trailer can leave Samutsongkhram in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.9.

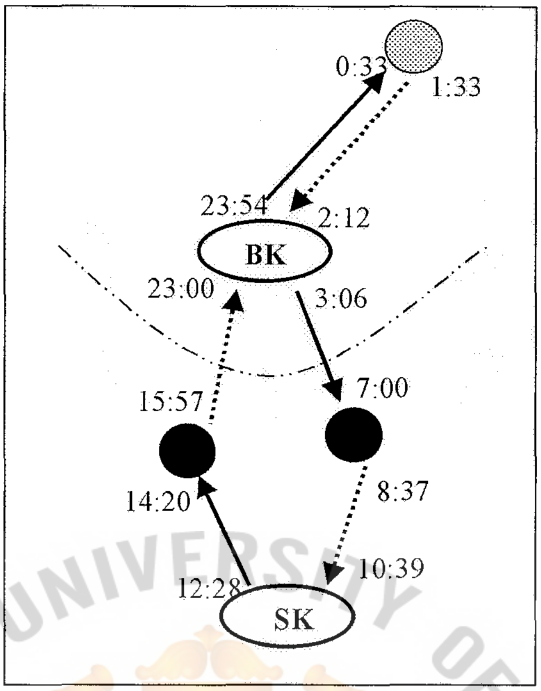


Figure 4.9. The Route Model between Bangkok and Samutsongkhram of One Semi-Trailer.

(5) The Route between Bangkok to Rayong (BK ↔ RY)

(a) The Route Model of 10 Wheeler

Due to ban hour and ban zone that allow the 10 wheeler run during 22:00 p.m.- 06:00 a.m., the first point will be started at 22:00 p.m. that 10 wheeler can enter Bangkok. The obtained data from company indicates that the time for arriving Bangkok depot is about 45 minutes. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to start entering Bangkok depot.

(2) The 10 wheeler spends 45 minutes for arriving Bangkok depot, so the time will be 22:45 p.m.

(3) Spends 46 minutes before driving to the customer's site as Table 4.1, so the time will be 23:31 p.m.

(4) Spends 39 minutes for driving to customer's site, so the time will be 0:10 a.m.

(5) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 0:50 a.m.

(6) Spends 39 minutes for driving to Bangkok depot, so the time will be 1:29 a.m.

(7) Spends 46 minutes before driving to the customer's site, so the time will be 2:15 a.m.

(8) Spends 39 minutes for driving to the customer's site, so the time will be 2:54 a.m.

(9) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 3:34 a.m.

(10) Spend 39 minutes for driving to Bangkok depot, so the time will be 4:13 a.m.

(11) Spend 46 minutes before driving to the customer's site, so the time will be 4:59 a.m.

At 4:59 a.m., the 10 wheeler will be operated to deliver product to customer in Rayong because the remainder time is only 1 hour that is not enough to be operated to deliver the oil product to customer in Bangkok. However, the time of receiving order of upcountry customers start at 7:00 a.m. where the distance between Rayong and Bangkok is approximately 176 kilometers. Moreover, the transportation law allows the maximum speed of running the 10 wheeler is 80 km./hr. Therefore, the 10 wheeler can arrive the customer site at 7:00 a.m. It will be then operated by spending the operation time of Rayong depot as Table 4.1 as follows:

(1) Spends 66 minutes for unloading oil product at the customer's site, so the time will be 8:06 a.m.

(2) Spends 182 minutes for driving to Rayong depot, so the time will be 11:08 a.m.

(3) Spends 118 minutes before driving to the customer's site, so the time will be 13:06 p.m.

(4) Spends 165 minutes for driving to the customer's site, so the time will be 15:51 p.m.

(5) Spends 66 minutes for unloading the oil product at the customer's site, so the time will be 16:57 p.m.

At 16:57 p.m., the 10 wheeler will finish unloading the oil product at customer's site in Rayong. Since the depot is closed at 16:30 p.m. and the remainder time is 5 hours and 3 minutes, the 10 wheeler can leave Rayong in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, the route model can be created as Figure 4.10.

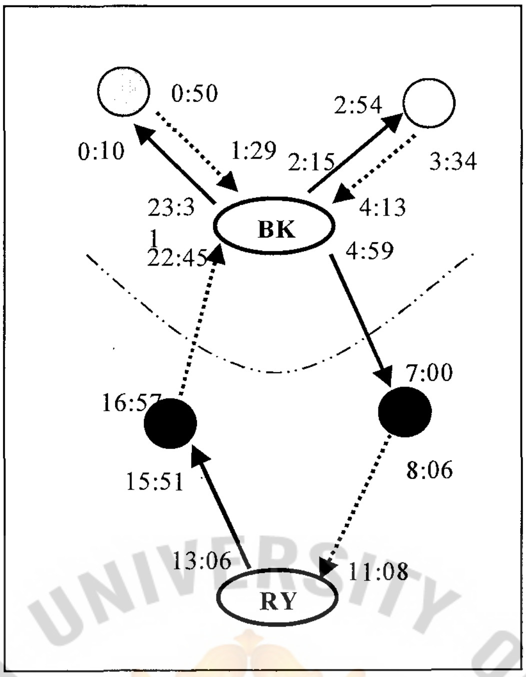


Figure 4.10. The Route Model between Bangkok and Rayong of One 10 Wheeler.

(b) The Route Model of Semi-Trailer

Due to the transportation law that allows the semi-trailer run during 22:00 p.m. – 05:00 a.m., the first point will be started at 22:00 p.m. when the semi-trailer can enter Bangkok. The obtained data from the company indicates that the time for arriving Bangkok depot is about 60 minutes or 1 hour. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to enter Bangkok depot.

(2) The semi-trailer spends 60 minutes for arriving Bangkok depot, so the time will be 23:00 p.m.

(3) And then spends 54 minutes before driving to the customer's site as Table 4.2, so the time will be 23:54 p.m.

(4) Spends 39 minutes for driving to the customer's site, so the time will be 0:33 a.m.

(5) Spends 60 minutes for unloading the oil product at the customer's site, so the time will be 1:33 a.m.

(6) Spends 39 minutes for driving back Rayong depot, so the time will be 2:12 a.m.

(7) Spends 54 minutes before driving to the customer's site, so the time will be 3:06 a.m.

At 3:06 a.m., the semi-trailer will be operated to deliver the oil product to the customer in Rayong because the remainder time is only 1 hour and 54 minutes which is not enough to be operated to deliver the oil product to the customer in Bangkok. However, the time of receiving order of upcountry customers will start at 7:00 a.m. where the distance between Rayong and Bangkok is 187 kilometers. Moreover, the transportation law allow the maximum speed of running the semi-trailer is 60 km./hr. Therefore, the semi-trailer can arrive the customer at 7:00 a.m. It will be then operated by spending the operation time of Rayong depot as follows:

(1) Spends 99 minutes for unloading oil product at the customer's site, so the time will be 8:39 a.m.

(2) Spends 182 minutes for driving to Rayong depot, so the time will be 11:41 a.m.

(3) Spends 133 minutes before driving to the customer's site, so the time will be 13:54 p.m.

(4) Spends 165 minutes for driving to the customer's site, so the time will be 16:39 p.m.

(5) Spends 99 minutes for unloading the oil product at the customer's site, so the time will be 18:18 p.m.

At 18:18 p.m., the semi-trailer will finish unloading the oil product at the customer's site in Rayong. Since the depot is closed at 16:30 p.m. the remainder time is 3 hours and 42 minutes. So, the semi-trailer can leave Rayong in order to prepare to enter Bangkok depot at 22:00 p.m. From the description and procedures that are described above, The route model can be created as Figure 4.11.

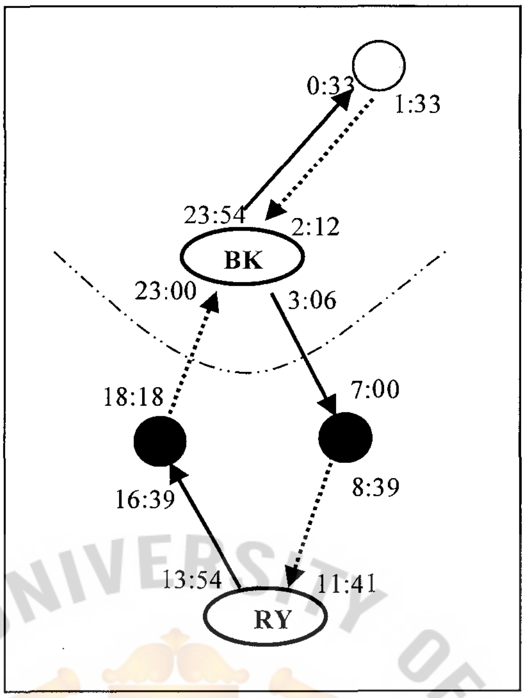


Figure 4.11. The Route Model between Bangkok and Rayong of One Semi-Trailer.

(6) The Route within Bangkok (BK ↔ BK)

(a) The Route Model of 10 Wheeler

Because the transportation law allows, the 10 wheeler can run during 22:00 p.m. – 06:00 a.m. So, the first point will be started at 22:00 p.m. when 10 wheeler can run in Bangkok. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to leave Bangkok depot.

(2) Spends 39 minutes for driving to the customer's site, so the time will be 22:39 p.m.

(3) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 23:19 p.m.

(4) Spends 39 minutes for driving back Bangkok depot, so the time will be 23:58 p.m.

(5) Spends 46 minutes before driving to the customer's site, so the time will be 0:44 a.m.

(6) Spends 39 minutes for driving to the customer's site, so the time will be 1:23 a.m.

(7) Spends 40 minutes for unloading the oil product at the customer's site, so the time will be 2:03 a.m.

(8) Spends 39 minutes for driving to Bangkok depot, so the time will be 3:42 a.m.

At 3:42 a.m., the 10 wheeler will stop operation at Bangkok depot because of the regulation that allows to run during 22:00 p.m.-06:00 a.m. and the remainder time is 2 hours and 18 minutes that is not enough to be operated to deliver the oil product to customers. From the description and procedures that are described above, the route model can be created as Figure 4.12.

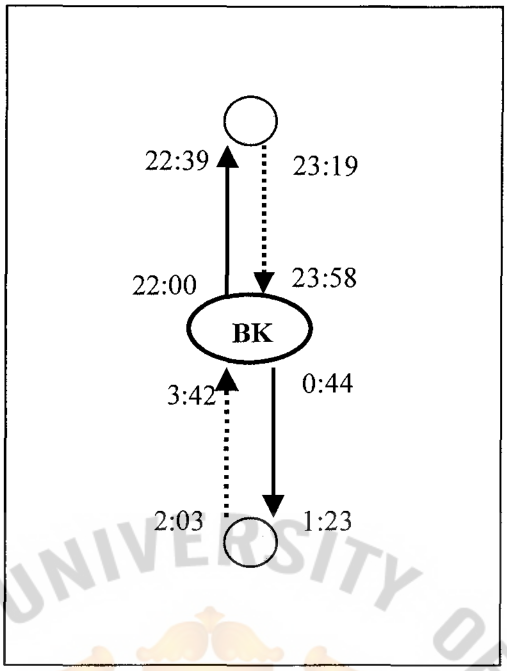


Figure 4.12. The Route Model within Bangkok of One 10 Wheeler.

(b) The Route Model of Semi-Trailer

Due to the transportation law that allows, the semi-trailer can run during 22:00 p.m. – 05:00 a.m. So, the first point will be started at 22:00 p.m. that the semi-trailer can run in Bangkok. The procedures of designing model are as follows:

(1) The first point is started at 22.00 p.m. in order to leave Bangkok depot.

(2) Spends 39 minutes for driving to the customer's site, so the time will be 22:39 p.m.

(3) Spends 60 minutes for unloading the oil product at the customer' site, so the time will be 23:39 p.m.

(4) Spends 39 minutes for driving to Bangkok depot, so the time will be 0:18 a.m.

(5) Spends 54 minutes before driving to the customer's site, so the time will be 1:12 a.m.

(6) Spends 39 minutes for driving to the customer's site, so the time will be 1:51 a.m.

(7) Spends 60 minutes for unloading the oil product at the customer's site, so the time will be 2:51 a.m.

(8) Spends 39 minutes for driving to Bangkok depot, so the time will be 3:30 a.m.

At 3:30 a.m., the semi-trailer will stop operation at Bangkok depot because of the regulation that allow to run during 22:00 p.m.-05:00 a.m. So, the remainder time is 1 hours and 30 minutes that is not enough to be operated to deliver the oil product to customers. From the description and procedures that are described above, the route model can be created as Figure 4.13.

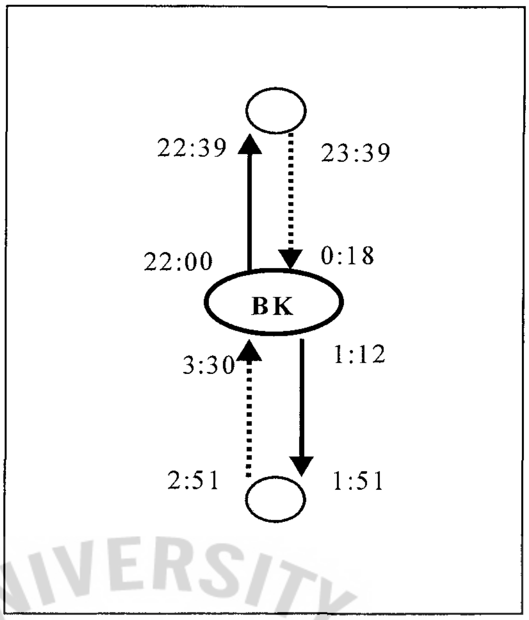


Figure 4.13. The Route Model within Bangkok of One Semi-Trailer.

4.2 Linear Programming Model of the New Transportation System

The new transportation system is the transportation system that has the optimal number of tankers but they should be operated both in Bangkok and upcountry as much as possible. This project will focus on transportation route between Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong.

4.2.1 The Related Factors of Formulation Linear Programming Model

There are several factors that the company must consider for calculation in order to obtain the optimal number of tankers to minimize the transportation cost following the new transportation system as follows:

(1) The shift working's time for the operation of drivers can be shown in Table 4.4.

Table 4.4. The Shift Working's Time of Each Depot.

Depot	**Working Time (Hours.)**		
	1 Shift	**2 Shifts**	**3 Shifts**
BK	8	0	0
PT	10	20	24
AU	10	20	24
SB	10	20	24
SK	10	20	24
RY	10	20	24

(2) The operating cost can be separated into 2 types that are fixed cost and variable cost as follows:

(a) Fixed cost is not varied on running of the tankers. The components of fixed cost are as follows:

(1) Annuity Capital.

(2) License.

(3) Insurance.

(4) Driver's Uniform.

(5) Personal Protective Equipment (PPE) such as glove, helmets and shoes.

(6) Salary.

(7) Profit allowance.

(8) Administration Cost.

(9) Battery Cost.

The fixed cost of one 10 wheeler and one semi-trailer in year 1999 is obtained from the company is shown in Table 4.5.

Table 4.5. Fixed Cost of the 10 Wheeler and the Semi-Trailer in Year 1999.

Tanker / Description	10 Wheeler			Semi-Trailer		
	1 Shift	**2 Shifts**	**3 Shifts**	**1 Shift**	**2 Shifts**	**3 Shifts**
Annuity Capital	162,606	202,281		249,261	312,661	
License	4,200	4,200		8,400	8,400	
Insurance	12,500	12,500		25,000	25,000	
Driver`s Uniform	1,300	2,600		1,300	2,600	
PPE	1,620	3,240		1,620	3,240	
Salary	150,000	300,000		180,000	360,000	
Profit Allowance	54,000	97,200		60,000	108,000	
Admin. Cost	18,000	18,000		18,000	18,000	
Battery Cost	1,800	1,800		1,800	1,800	
Total Cost (bahts per year)	**406,026**	**641,821**		**545,381**	**839,701**	
Total Cost (bahts per day)	**1,127.85**	**1,782.84**		**1,514.95**	**2,332.50**	

(b) Variable cost is varied on the distance of the tankers, which has unit of bahts per kilometer. The variable cost of 10 wheeler is 9.25 bahts per kilometer. For the variable cost of semi-trailer is 14.31 bahts per kilometer. The assumptions of variable cost are as follows:

(1) Fuel consumption.

(2) Lubricating oil consumption.

(3) Tire consumption.

(4) Maintenance cost.

(5) Gas oil price is 10.25 bahts/liter.

The average distance of a tanker that is located in each depot obtained by the company can be shown in Table 4.6.

Table 4.6. The Average Distance (One-Way) of the Tanker.

Depot	Distance of one Tanker (km./one-way)
BK	28.36
PT	56.13
AU	65.56
SB	65.31
SK	75.35
RY	138.94

From the route model in section 4.1, Tables 4.3, and 4.6. Therefore, the distance per day that one tanker is operated to deliver the oil product to customers can obtain as in Table 4.7.

Table 4.7. The Distance of One Tanker per Day.

Depot	Distance(km./day)	
	10 Wheeler	Semi-Trailer
BK	113.44	113.44
PT	383.96	214.98
AU	435.68	378.96
SB	359.06	302.34
SK	351.14	294.42
RY	567.32	510.60

Therefore, you can calculate the variable cost per day of a tanker by:

The variable cost of one tanker per day

= The variable cost (bahts per kilometer)

x

The average distance of one tanker per day (kilometer)

Table 4.8 shows the variable cost of one tanker per day that calculate from the above formula.

Table 4.8. The Variable Cost of One Tanker per Day.

Depot	10 Wheeler (bahts/day)	Semi-Trailer (bahts/day)
BK	1,049.16	1,623.33
PT	3,551.08	3,076.36
AU	4,029.42	5,422.92
SB	3,320.79	4,326.49
SK	3,247.54	4,213.15
RY	5,246.90	7,306.69

(3) The volume of oil that the company sales to customers in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong in year 1999 as Table 4.9.

Table 4.9. The Sales Volume of Oil in Year 1999.

Depot	Volume(liters./year)
BK	1,034,155,600
PT	54,580,300
AU	51,073,900
SB	38,041,000
SK	120,546,400
RY	255,485,600

(4) The number of all trips or orders per day that each depot operates to deliver the oil product to customers.

The company's policies state that customers should order 15,000 liters or 30,000 liters per shipment. That means the minimum volume of oil per one trip or one order is 15,000 liters that is carried by one 10 wheeler.

From Table 4.9, you already get the value of sales volume per year of each depot. Therefore, you can calculate the number of trips or orders per day by

$$\text{Number of Trips/Day} = \frac{\text{Volume per year(liters.)}}{15{,}000\text{liters} * 12\text{months} * 30\text{days}}$$

Remark: The number of working days per month is 30 days or 360 days per year.

Table 4.10 shows the number of trips per day that calculate from above formula.

Table 4.10. The Number of Trips per Day.

Depot	Volume(liter./year)	Trips/Day
BK	1,034,155,600	191.51
PT	54,580,300	10.11
AU	51,073,900	9.46
SB	38,041,000	7.04
SK	120,546,400	22.32
RY	255,485,600	47.31

(5) The number of trips or orders per day that one 10 wheeler or one semi-trailer is operated to deliver the oil product to customers.

According to the loading capacity of a semi-trailer is 30,000 liters that means it is double capacity of one 10 wheeler. In other words is one order or trip of semi-trailer is equivalent to 2 orders or trips of 10 wheelers.

From the tanker's routing model in section 4.1 can summarize the number of trips or orders that one 10 wheeler or one semi-trailer is operated to deliver the oil product to customers each day as in Table 4.11.

Table 4.11. The Number of Trips or Orders of 10 Wheeler and Semi-Trailer.

Route	10 Wheeler		Semi-Trailer	
	Upcountry's order	Bangkok's order	Upcountry's order	Bangkok's order
BK ↔ PT	3	2	4	2
BK ↔ AU	3	2	6	2
BK ↔ SB	2	2	4	2
BK ↔ SK	2	2	4	2
BK ↔ RY	2	2	4	2

(6) The existent number of 10 wheelers and semi-trailers that are operated at each depot in the present are shown in Table 4.12.

Table 4.12. The Existent Number of 10 Wheeler and Semi-Trailer.

Depot	Number of Tankers	
	10 Wheeler	**Semi-Trailer**
PT	3	2
AU	7	1
SB	7	0
SK	8	5
RY	32	6
BK	68	1
Total	**125**	**15**

4.2.2 Formulation of the Linear Programming Model

The concept of linear programming model is described in chapter 2. This section is the formulation linear programming model in order to obtain the appropriate number of tankers to minimize the transportation cost. The model consists of the objective function and the constraint function, which has characteristics as follows:

(1) The Objective Function

The objective function is determined by calculating the number of tankers that minimizes the transportation cost.

(2) The Constraint Function

The constraints and conditions of decision variables that are used to formulate the model are as follows:

(a) The existent number of tankers that is shown in Table 4.12.

(b) The number of order that each depot is operated to delivery product to customers each day that is shown in Table 4.10.

(c) The number of order per day that one 10 wheeler or one semi-trailer can operate to deliver the oil product to customers that is shown in Table 4.11.

From (1) and (2) the linear programming model can be written as follows:

Minimize Cost $\sum_{j=1}^{2}\sum_{i=1}^{5} F_j X_{ij} + \sum_{j=1}^{2}\sum_{i=1}^{5} V_{ij} X_{ij}$

Subject to

$$\sum_{i=1}^{5} X_{i1} \leq N_1 \qquad (1.1)$$

$$\sum_{i=1}^{5} X_{i2} \leq N_2 \qquad (1.2)$$

$$T_{11}X_{11} + T_{12}X_{12} \geq O_1 \qquad (1.3)$$

$$T_{21}X_{21} + T_{22}X_{22} \geq O_2 \qquad (1.4)$$

$$T_{31}X_{31} + T_{32}X_{32} \geq O_3 \qquad (1.5)$$

$$T_{41}X_{41} + T_{42}X_{42} \geq O_4 \qquad (1.6)$$

$$T_{51}X_{51} + T_{52}X_{52} \geq O_5 \qquad (1.7)$$

let j = 1, 2 : The types of tankers by

1 = The 10 Wheeler

2 = The Semi-Trailer

i =1,…,5 : Upcountry depots by

1 = Pathumtanee Depot

2 = Ayutthaya Depot

3 = Saraburi Depot

4 = Samutsongkhram Depot

5 = Rayong Depot

F_j = Fixed cost per day of tanker j

V_{ij} = Variable cost per day of tanker j at depot i

X_{ij} = The number of tanker j in depot i

X_{i1} = The number of 10 wheelers in depot i

X_{i2} = The number of semi-trailers in depot i

N_1 = The existent number of 10 wheelers

N_2 = The existent number of semi-trailers

T_{11} = The number of or trips or orders per day that one 10 wheeler is operated in Pathumtanee.

T_{12} = The number of trips or orders per day one that one semi-trailer is operated in Pathumtanee.

T_{21} = The number of trips or orders per day that one 10 wheeler is operated in Ayutthaya.

T_{22} = The number of trips or orders per day that one semi-trailer is operated in Ayutthaya.

T_{31} = The number of trips or orders per day that one 10 wheeler is operated in Saraburi.

T_{32} = The number of trips or orders per day that one semi-trailer is operated in Saraburi.

T_{41} = The number of trips or orders per day one 10 wheeler is operated in Samutsongkhram.

T_{42} = The number of trips or orders per day that one semi-trailer is operated in Samutsongkhram.

T_{51} = The number of trips or orders per day that one 10 wheeler is operated in Rayong.

T_{52} = The number of trips or orders per day that one semi-trailer is operated in Rayong.

O_1 = The number of all trips or orders per day that Pathumtanee depot is operated to deliver oil product to customers.

O_2 = The number of all trips or orders per day that Ayutthaya depot is operated to deliver oil product to customers.

O_3 = The number of all trips or orders per day that Saraburi depot is operated to deliver oil product to customers.

O_4 = The number of all trips or orders per day that Samutsongkhram depot is operated to deliver oil product to customers.

O_5 = The number of all trips or orders per day that Rayong depot is operated to deliver oil product to customers.

Therefore, the linear programming model that replaces of the values from Tables 4.5, 4.8, 4.10, 4.11, and 4.12 can be written as follows:

$$\text{Minimize Cost} \quad 1{,}782.84\sum_{i=1}^{5} X_{i1} + 2{,}332.50\sum_{i=1}^{5} X_{i2} + 3{,}551.08X_{11} + 3{,}076.36X_{12}$$
$$+ 4{,}029.42X_{21} + 5{,}422.92X_{22} + 3{,}320.79X_{31} + 4{,}326.49X_{32}$$
$$+ 3{,}247.54X_{41} + 4{,}213.15X_{42} + 5{,}246.90X_{51} + 7{,}306.69X_{52}$$

Subject to

$$X_{11} + X_{21} + X_{31} + X_{41} + X_{51} \leq 125 \quad (1.1)$$

$$X_{12} + X_{22} + X_{32} + X_{42} + X_{52} \leq 15 \quad (1.2)$$

$$3X_{11} + 4X_{12} \geq 10.11 \quad (1.3)$$

$$3X_{21} + 6X_{22} \geq 9.46 \quad (1.4)$$

$$2X_{31} + 4X_{32} \geq 7.04 \quad (1.5)$$

$$2X_{41} + 4X_{42} \geq 22.32 \quad (1.6)$$

$$2X_{51} + 4X_{52} \geq 47.31 \quad (1.7)$$

4.3 The Calculation of the Tankers' Number in Bangkok Depot

The optimization tool in this project is Lindo programming. This tool is good computer software that can solve linear programming model of the new transportation system in the section 4.2.2. as in Table 4.13.

Table 4.13. The Optimum Solution Summary of the New Transportation System.

LP OPTIMUM FOUND AT STEP 8

OBJECTIVE FUNCTION VALUE

1) 212651.9

VARIABLE	VALUE	REDUCED COST
X11	3.370000	0.000000
X12	0.000000	1845.236572
X21	0.000000	160.414764
X22	1.576667	0.000000
X31	0.328334	0.000000
X32	1.595833	0.000000
X41	11.160000	0.000000
X42	0.000000	33.159901
X51	0.000000	436.010223
X52	11.827500	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	110.141663	0.000000
3)	0.000000	3548.270020
4)	0.000000	-1777.973389
5)	0.000000	-1883.948364
6)	0.000000	-2551.814941
7)	0.000000	-2515.189941
8)	0.000000	-3296.864990

Therefore, The results that are obtained by Lindo program can summarize in Table 4.14.

Table 4.14. The Obtained Result from Lindo Programing.

Depot	Number of Tankers	
	10 Wheeler	Semi-Trailer
Pathumtanee	3.37	0
Ayutthaya	0	1.5767
Saraburi	0.3283	1.5958
Samutsongkhram	11.16	0
Rayong	0	11.8275

From Table 4.11, you already get the number of trips or orders per day that a tanker can operate to deliver the oil product to customers. So, you can calculate the number of Bangkok's trips or orders.

The number of trips or orders in Bangkok

= The number of trips or orders per day of 10 wheeler and semi-trailer

x

The number of 10 wheelers or semi-trailers in Table 4.14.

From the above formula the result can be shows as Table 4.15.

Table 4.15. The Number of Trips or Orders in Bangkok That Upcountry Depot's Tankers Can Operate to Deliver Products to Customers.

Depot	10 Wheeler	Semi-Trailer
Pathumtanee	6.74	0
Ayutthaya	0	3.1534
Saraburi	0.6566	3.1916
Samutsongkhram	22.32	0
Rayong	0	23.655
Total	**29.7166**	**30**
Grand Total		**59.7166**

From Table 4.10, the number of trips per day in Bangkok is 191.51 trips. Because of one trip or one order is equivalent to 15,000 liters and the number of semi-trailer is obtained by Lindo program equal to the existent number of semi-trailer. So, the tankers that should be located in Bangkok depot are the 10 wheelers, which the remainder of oil's volume that will be delivered by them can be calculated by:

The remainder of oil's volume

= 191.51 trips – 59.7166 trips

= 131.7934 trips

From Figure 4.12, the number of trips or orders per day that one 10 wheeler can operate is 2 trips. So, You can calculate the number of 10 wheelers by:

$$\text{Number of 10 wheelers} = \frac{\text{The remainder of oil's volume(trips)}}{2}$$

$$= \frac{131.7934}{2}$$

$$= 65.8967 \quad \text{or } 66$$

Therefore, the summarization of number of 10 wheelers and semi-trailers that is located in each depot can be shown in Table 4.16.

Table 4.16. The Summarization of Tankers' Number in Each Depot.

Depot	10 Wheeler	Semi-Trailer
Bangkok	66	0
Pathumtanee	3.37	0
Ayutthaya	0	1.5767
Saraburi	0.3283	1.5958
Samutsongkhram	11.16	0
Rayong	0	11.8275

So, you can calculate the transportation cost per day by:

212,651.90 + 66x(1,127.85+1,049.16) = 356,334.42 bahts/day.

From the principle of linear programming that allows the solutions are in terms of fractional or noninteger as the obtained result by Lindo programming that is shown in Table 4.13. In this project, the author will use rounding up the number of tanker into integer in order to apply in the real world. By rounding up the values, the number of tankers will be changed as Table 4.17.

Table 4.17. The Number of Tankers in Each Depot That Is Rounded Up.

Depot	Number of Tankers	
	10 Wheeler	Semi-Trailer
Pathumtanee	4	0
Ayutthaya	0	2
Saraburi	1	2
Samutsongkhram	12	0
Rayong	0	12

According to the solution method of the number of Bangkok's tankers as the author describes above. The summarization of the number of tankers in each depot can be shown in Table 4.18.

Table 4.18. The Summarization of Tankers' Number in Each Depot by Rounding Up Method.

Depot	Number of Tankers	
	10 Wheeler	Semi-Trailer
Bangkok	63	0
Pathumtanee	4	0
Ayutthaya	0	2
Saraburi	1	2
Samutsongkhram	12	0
Rayong	0	12
Total	**80**	**16**

From Table 4.18, the transportation cost is equal to 368,454.46 bahts/day. So, the transportation cost that is obtained by rounding up the number of tankers will be difference from the principle of linear programming equal to 12,120.03 bahts per day.

The next chapter will analyze the result of Linear Programming Model. Moreover, the author will describe the change of values or sensitivity analysis.

V. THE SENSITIVITY ANALYSIS

In this chapter, the author divides the analysis into 2 parts. The first part is the analysis of the obtained results from linear programming model in chapter 4. The second part is the sensitivity analysis.

5.1 Analysis of the Results of the Linear Programming Model

According to the transportation system in the present, the tankers are operated to deliver oil product to customers in their area. It is different from the new transportation system that has the optimal number of tankers in operation to deliver the oil product to customers in both upcountry and Bangkok as much as possible. Both of the transportation systems make the cost of operation differently that can compare and be shown in Table 5.1.

Table 5.1. The Comparison between the Current System and the New System.

	The Current System	The New System	Different Values	Percentage of Change
Transportation Cost (bahts/day)	433,343.41	356,334.42	-77,008.98	-17.77%
Number of 10 Wheelers	125	81	-44	-35.20%
Number of Semi-Trailers	15	15	0	0

As Table 5.1, the new transportation system can save cost about 77,008.98 bahts/day or 17.77% of the current system because the number of 10 wheelers are reduced by 35.20%.

5.2 The Sensitivity Analysis

The objective of sensitivity analysis is to consider the change of coefficients or parameters in linear programming model as to how they effect to the results of the model. In this project, the author will consider about the changes of coefficients as follows:

(1) The Cost Changes

From the linear programming model in section 4.2.2, the transportation cost consists of fixed cost and variable cost. Fixed cost is not varied on the tanker's running. But variable cost is varied on the distance that the tanker is operated to deliver the oil product to customers'site, which has a unit of bahts per kilometer.

Due to the change of diesel price in the present, it effects to the variable cost of transportation. The diesel price that is used in the linear programming model in section 4.2.2 is 10.25 bahts per liter but in this situation, the price of diesel is uncertain. Therefore, to obtain the result that close the real situation, the author will consider the changes of the diesel price at 25%.

(a) Increasing Diesel's Price by 25%

The price of diesel in linear programming model is estimated at 10.25 bahts per liter. The diesel price that increases 25% is 12.81 bahts per liter that the variable cost of a 10 wheeler is 9.98 bahts per kilometer and variable cost of a semi-trailer is 15.33 bahts per kilometer. Therefore, the objective function in section 4.2.2 will be changed as follows:

$$\text{Minimize Cost} \quad 1{,}782.84\sum_{i=1}^{5} X_{i1} + 2{,}332.50\sum_{i=1}^{5} X_{i2}$$
$$+ 3{,}831.92X_{11} + 3{,}296.50X_{12} + 4{,}348.09X_{21} + 5{,}810.97X_{22}$$
$$+ 3583.42X_{31} + 4{,}636.08X_{32} + 3504.38X_{41} + 4{,}514.64X_{42}$$
$$+ 5{,}661.85X_{51} + 7{,}829.54X_{52}$$

The optimum summary of the new linear programming model is shown in Table 5.2.

Table 5.2. The Optimum Solution Summary of Increasing Diesel's Price by 25%.

LP OPTIMUM FOUND AT STEP 0

OBJECTIVE FUNCTION VALUE

1) 223840.8

VARIABLE	VALUE	REDUCED COST
X11	3.370000	0.000000
X12	0.000000	1906.593384
X21	0.000000	177.225174
X22	1.576667	0.000000
X31	0.328334	0.000000
X32	1.595833	0.000000
X41	11.160000	0.000000
X42	0.000000	36.640137
X51	0.000000	481.699951
X52	11.827500	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	110.141663	0.000000
3)	0.000000	3763.939941
4)	0.000000	-1871.586670
5)	0.000000	-1984.568359
6)	0.000000	-2683.129883
7)	0.000000	-2643.610107
8)	0.000000	-3481.495117

From the solution method of the number of tankers in Bangkok depot, it can summarize and compare to the current system as in Table 5.3.

Table 5.3. The Comparison of the Results of Increasing Diesel's Price by 25%.

	New System (at diesel 10.25 bahts/liter)	New System (at diesel 12.81 bahts/liter)	Difference Values	Percentage of Change
Transportation Cost (bahts/day)	356,334.42	372,998.76	16,664.33	4.68%
Number of 10 Wheelers	81	81	0	0
Number of Semi-Trailers	15	15	0	0

Table 5.3 shows that when the price of diesel increases by 25%, the transportation cost will increase 16,664.33 bahts/day or 4.68%. However, the number of tankers is still not changed.

(b) Decreasing Diesel Price by 25%

The diesel price that decrease 25% is 7.69 bahts per liter that the variable cost of a 10 wheeler is 8.52 bahts per kilometer and variable cost of a semi-trailer is 13.29 bahts per kilometer. Therefore, the objective function in section 4.2.2 will be changed as follows:

$$\text{Minimize Cost} \quad 1{,}782.84\sum_{i=1}^{5} X_{i1} + 2{,}332.50\sum_{i=1}^{5} X_{i2}$$
$$+3{,}270.24X_{11} + 2{,}856.22X_{12} + 3{,}710.75X_{21} + 5{,}037.86X_{22}$$
$$+3{,}058.17X_{31} + 4{,}016.89X_{32} + 2{,}990.71X_{41} + 3{,}911.66X_{42}$$
$$+4{,}831.95X_{51} + 6{,}783.83X_{52}$$

The optimum summary of the new linear programming model can be shown in Table 5.4.

Table 5.4. The Optimum Solution Summary of Decreasing Diesel Price by 25%.

LP OPTIMUM FOUND AT STEP 0

OBJECTIVE FUNCTION VALUE

1) 201463.0

VARIABLE	VALUE	REDUCED COST
X11	3.370000	0.000000
X12	0.000000	1783.910156
X21	0.000000	143.594849
X22	1.576667	0.000000
X31	0.328334	0.000000
X32	1.595833	0.000000
X41	11.160000	0.000000
X42	0.000000	29.690157
X51	0.000000	390.310028
X52	11.827500	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	110.141663	0.000000
3)	0.000000	3332.629883
4)	0.000000	-1684.359985
5)	0.000000	-1783.331665
6)	0.000000	-2420.504883
7)	0.000000	-2386.774902
8)	0.000000	-3112.239990

From the solution method of the number of tankers in Bangkok depot, it can summarize and compare to the linear programming model in section 4.2.2 as in Table 5.5.

Table 5.5. The Comparison of the Results of Decreasing Diesel's Price by 25%.

	The System (at diesel 10.25 bahts/liter)	**The System (at diesel 7.69 bahts/liter)**	**Difference Values**	**Percentage of Change (%)**
Transportation Cost (bahts/day)	356,334.42	339,669.29	-16,665.13	-4.68%
Number of 10 Wheelers	81	81	0	0
Number of Semi-Trailers	15	15	0	0

As in Table 5.5, when the price of diesel decreases by 25%, the transportation cost will decrease 16,665.13 bahts/day or 4.68%. However, the number of tankers is still not changed.

(2) Right Hand Side Changes

(a) The Number of Trips or Orders per Day in Each Depot

The company can not determine the number of trips or orders per day exactly. The number of orders can increase or decrease depends on the economic situation in the present, which effects to allocate the appropriate number of tankers. Therefore, to obtain the result that closes the real situation, the author will consider the changes of the number of orders per day at 15%.

(1) Increasing the number of trips or orders by 15%

From the Table 4.10, the number of trips or orders per day that depot in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong operate to deliver the oil product to customers is 191.51, 10.11, 9.46, 7.04, 22.32, and 47.31 trips respectively. So, the number of trips or orders that increases by 15% will be 220.24, 11.62, 10.88, 8.10, 25.67, and 54.41 trips respectively which change the constraint functions in section 4.2.2 as follows:

$$3X_{11} + 4X_{12} \geq 11.62$$

$$3X_{21} + 6X_{22} \geq 10.88$$

$$2X_{31} + 4X_{32} \geq 8.10$$

$$2X_{41} + 4X_{42} \geq 25.67$$

$$2X_{51} + 4X_{52} \geq 54.41$$

The optimum solution summary of the new linear programming model can be shown in Table 5.6.

Table 5.6. The Optimum Solution Summary of Increasing the Orders' Number by 15%.

LP OPTIMUM FOUND AT STEP 2

OBJECTIVE FUNCTION VALUE

1) 252683.8

VARIABLE	VALUE	REDUCED COST
X11	3.873333	0.000000
X12	0.000000	2166.066650
X21	0.831667	0.000000
X22	1.397500	0.000000
X31	4.050000	0.000000
X32	0.000000	320.830231
X41	12.835000	0.000000
X42	0.000000	353.989899
X51	0.000000	275.595245
X52	13.602500	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	103.410004	0.000000
3)	0.000000	3869.100098
4)	0.000000	-1777.973389
5)	0.000000	-1937.420044
6)	0.000000	-2551.814941
7)	0.000000	-2515.189941
8)	0.000000	-3377.072510

From the solution method of the number of tankers in Bangkok depot, it can summarize and compare to the linear programming model in section 4.2.2 as in Table 5.7.

Table 5.7. The Comparison of Increasing the Number of Trips or Orders That Depots Operate Each Day by 15%.

	New System (at diesel 10.25 bahts/liter)	**Trips increase 15%**	**Difference Values**	**Percentage of Change (%)**
Transportation Cost (bahts/day)	356,334.42	413,782.39	57,447.96	16.12%
Number of 10 Wheelers	81	96	15	18.52%
Number of Semi-Trailers	15	15	0	0

As in Table 5.7, when the number of trips or orders increases by 15%, the transportation cost will increase 57,447.96 bahts/day or 16.12% because the number of 10 wheelers increases 18.52%.

(2) Decreasing the number of trips or orders by 15%

From the Table 4.10, the number of trips or orders per day that depot in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong operate to deliver the oil product to customers is 191.51, 10.11, 9.46, 7.04, 22.32, and 47.31 respectively. So, the number of trips or orders that decrease 15% will be 162.78, 8.59, 8.04, 5.99, 18.97, and 40.22 respectively which change the constraint functions in section 4.2.2 as follows:

$$3X_{11} + 4X_{12} \geq 8.59$$

$$3X_{21} + 6X_{22} \geq 8.04$$

$$2X_{31} + 4X_{32} \geq 5.99$$

$$2X_{41} + 4X_{42} \geq 18.97$$

$$2X_{51} + 4X_{52} \geq 40.22$$

The optimum solution summary of the new linear programming model can be shown in Table 5.8.

Table 5.8. The Optimum Solution Summary of Decreasing the Orders' Number by 15%.

LP OPTIMUM FOUND AT STEP 2

OBJECTIVE FUNCTION VALUE

1) 172864.0

VARIABLE	VALUE	REDUCED COST
X11	2.863333	0.000000
X12	0.000000	1812.076538
X21	0.000000	176.994766
X22	1.340000	0.000000
X31	0.000000	16.579884
X32	1.497500	0.000000
X41	5.270000	0.000000
X42	2.107500	0.000000
X51	0.000000	452.590240
X52	10.055000	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	116.866669	0.000000
3)	0.000000	3515.110107
4)	0.000000	-1777.973389
5)	0.000000	-1878.421631
6)	0.000000	-2543.524902
7)	0.000000	-2515.189941
8)	0.000000	-3288.574951

From the solution method of the number of tankers in Bangkok depot, it can summarize and compare to the linear programming model in section 4.2.2 as in Table 5.9.

Table 5.9. The Comparison of the Results of Decreasing the Number of Trips or Orders That Depots Operate Each Day by 15%.

	New System (at diesel 10.25 bahts/liter)	**Trips decrease 15%**	**Different Values**	**Percentage of Change (%)**
Transportation Cost (bahts/day)	356,334.42	301,307.47	-55,026.96	-15.44%
Number of 10 Wheelers	81	68	13	-16.05%
Number of Semi-Trailers	15	15	0	0

As Table 5.9, when the number of trips or orders decreases by 15%, the transportation cost will decrease 55,026.96 bahts/day or 15.44% because the number of the 10 wheelers decreases 16.05%.

(b) The number of tankers

In this project, the author will analyze the results when the number of tankers increase or decrease by 15%.

(1) Increasing the number of 10 wheelers and semi-trailers by 15%

From the existent number of 10 wheelers and semi-trailers located in the company's depots is 125 and 15 respectively. So, the number of 10 wheelers and semi-trailers that increase 15%

are 144, and 17 respectively which change the constraint functions in section 4.2.2 as follows:

$$X_{11}+X_{21}+X_{31}+X_{41}+X_{51} \leq 144$$

$$X_{12}+X_{22}+X_{32}+X_{42}+X_{52} \leq 17$$

The optimum solution summary of the new linear programming model can be shown in Table 5.10.

Table 5.10. The Optimum Solution Summary of Increasing Tankers' Number by 15%.

LP OPTIMUM FOUND AT STEP 0

OBJECTIVE FUNCTION VALUE

1) 205616.2

VARIABLE	VALUE	REDUCED COST
X11	3.370000	0.000000
X12	0.000000	1812.076538
X21	0.000000	176.994766
X22	1.576667	0.000000
X31	0.000000	16.579884
X32	1.760000	0.000000
X41	7.488334	0.000000
X42	1.835833	0.000000
X51	0.000000	452.590240
X52	11.827500	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	133.141663	0.000000
3)	0.000000	3515.110107
4)	0.000000	-1777.973389
5)	0.000000	-1878.421631
6)	0.000000	-2543.524902
7)	0.000000	-2515.189941
8)	0.000000	-3288.574951

From the solution method of the number of tankers in Bangkok depot, it can summarize and compare to the linear programming model in section 4.2.2 as in Table 5.11.

Table 5.11. The Comparison of the Results of Increasing the Tankers' Number by 15%.

	New System (at diesel 10.25 bahts/liter)	Tankers increase 15%	Different Values	Percentage of Change (%)
Transportation Cost (bahts/day)	356,334.42	353,652.74	-2,681.64	-0.75%
Number of 10 Wheelers	81	79	-2	-2.64%
Number of Semi-Trailers	15	17	2	13.33%

As in Table 5.11, when the number of tankers increases by 15%, the transportation cost will decrease 2,681.64 bahts/day or 0.75%. Thus the number of 10 wheelers and semi-trailers is 79 and 17 respectively. In other words, the number of 10 wheelers decrease by 2.64% but the number of semi-trailers increase by 13.33%.

(2) Decreasing the number of 10 wheelers and semi-trailers

The number of 10 wheelers and semi-trailers that decreases by 15% are 106, and 13 respectively which change the constraint functions in section 4.2.2 as follows:

$$X_{11}+X_{21}+X_{31}+X_{41}+X_{51} \leq 106$$

$$X_{12}+X_{22}+X_{32}+X_{42}+X_{52} \leq 13$$

The optimum solution summary of the new linear programming model can be shown in Table 5.12. From the solution method of the number of tankers in Bangkok depot, it can summarize and compare to the linear programming model in section 4.2.2 as in Table 5.13.

Table 5.12. The Optimum Solution Summary of Decreasing Tankers' Number by 15%.

LP OPTIMUM FOUND AT STEP 0

OBJECTIVE FUNCTION VALUE

1) 219878.1

VARIABLE	VALUE	REDUCED COST
X11	3.370000	0.000000
X12	0.000000	2166.066650
X21	0.808334	0.000000
X22	1.172500	0.000000
X31	3.520000	0.000000
X32	0.000000	320.830231
X41	11.160000	0.000000
X42	0.000000	353.989899
X51	0.000000	275.595245
X52	11.827500	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	87.141663	0.000000
3)	0.000000	3869.100098
4)	0.000000	-1777.973389
5)	0.000000	-1937.420044
6)	0.000000	-2551.814941
7)	0.000000	-2515.189941
8)	0.000000	-3377.072510

Table 5.13. The Comparison of the Results of Decreasing the Tankers' Number by 15%.

	New System (at diesel 10.25 bahts/liter)	Tankers decrease 15%	Different Values	Percentage of Change (%)
Transportation Cost (bahts/day)	356,334.42	359,206.61	2,872.18	0.81%
Number of 10 Wheelers	81	83	2	2.47%
Number of Semi-Trailers	15	13	-2	-13.33%

As Table 5.7, when the number of tankers decrease by 15%, the transportation cost will increase 2,872.18 bahts/day or 0.81%. Therefore the number of 10 wheelers and semi-trailers is 83 and 13 respectively. In other words, the number of 10 wheelers increase by 2.47% but the number of semi-trailers decrease by 13.33%.

From the sensitivity analysis, the obtained result can be shown in the terms of chart as Figures 5.1, 5.2, 5.3, 5.4.

Figure 5.1 can conclude that the new transportation can be more economic than the current system because the company can reduce the number of 10 wheeler by 35.20%. Moreover, when the price of diesel changes 1 bahts per liter effect to the transportation cost changes 1.83% (in the same direction) as in Figure 5.2.

The Comparison of the Current System and the New System

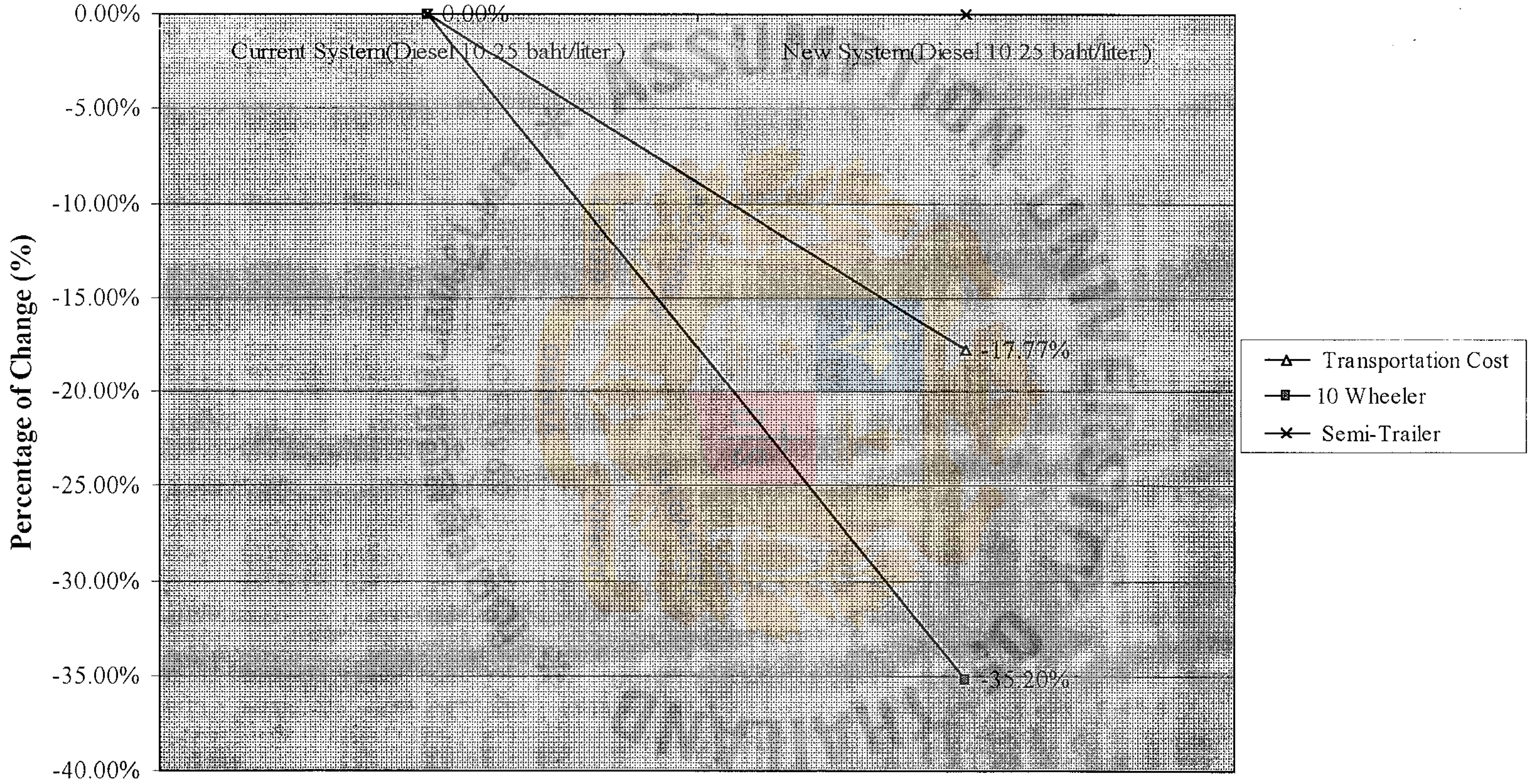


Figure 5.1. The Chart of Comparison of the Current System and the New System.

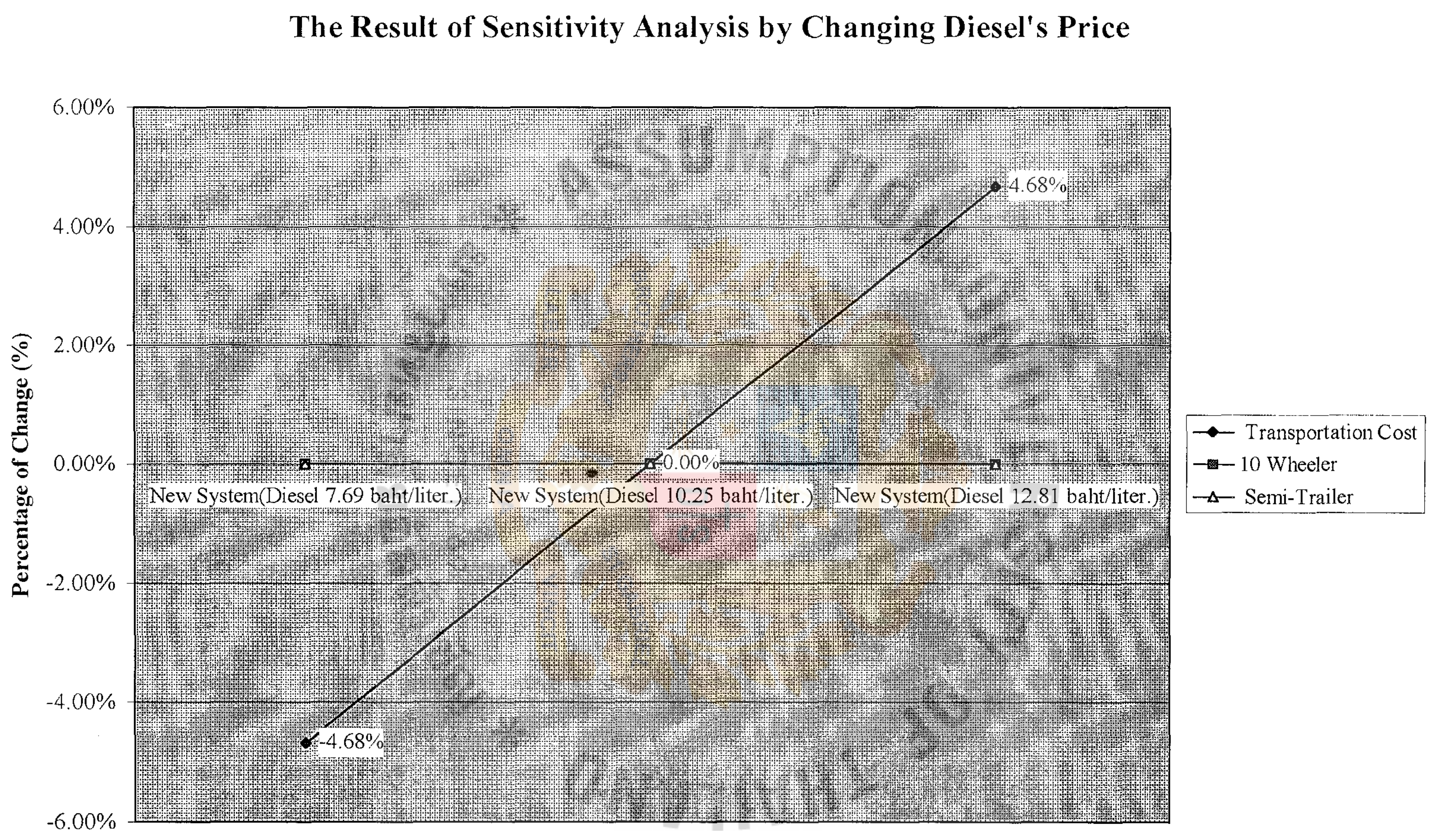


Figure 5.2. The Chart of Sensitivity Analysis by Changing Diesel's Price.

The Result of Sensitivity Analysis by Changing the Number of Trips or Orders

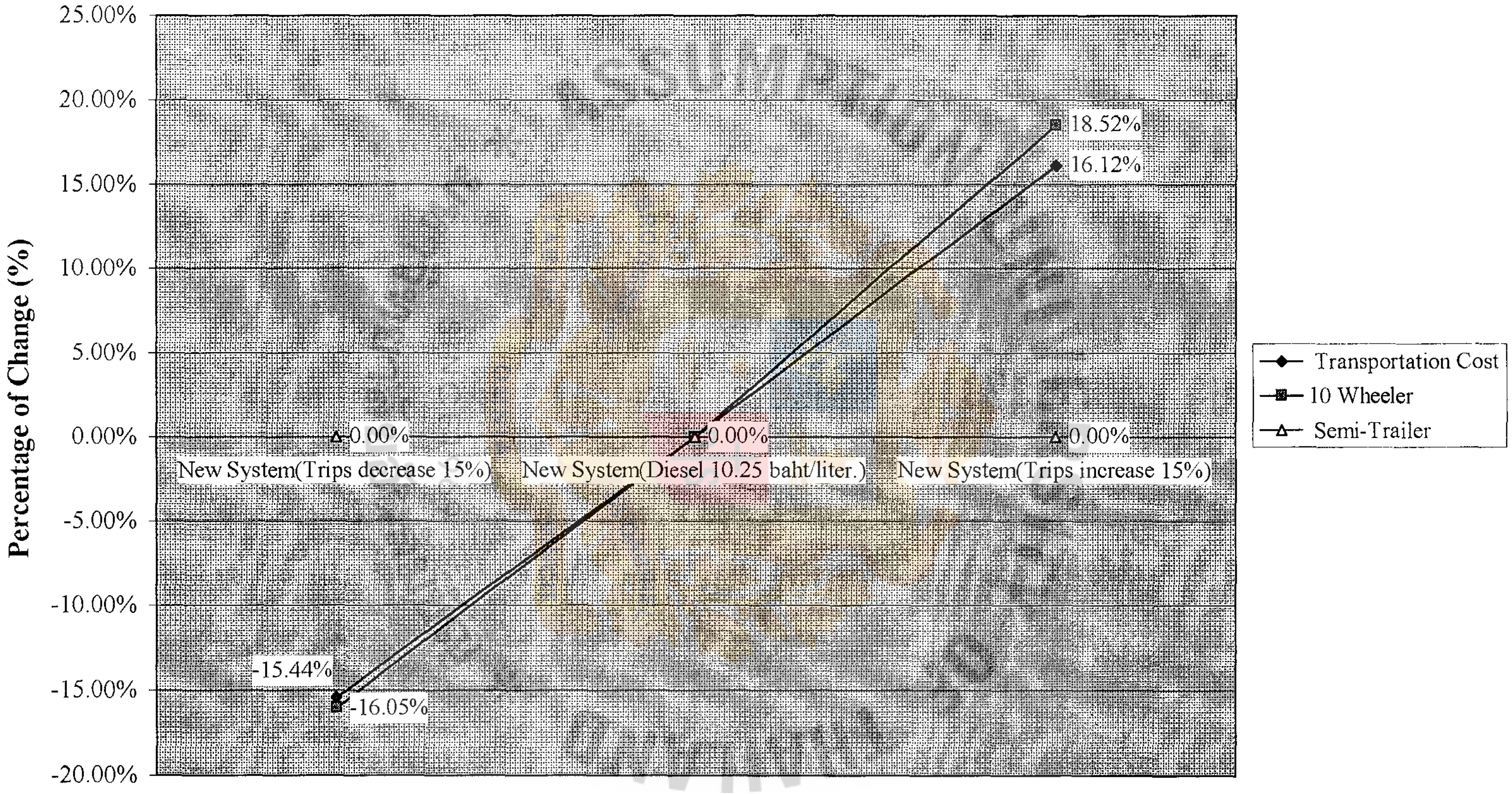


Figure 5.3. The Chart of Sensitivity Analysis by Changing the Number of Trips or Orders.

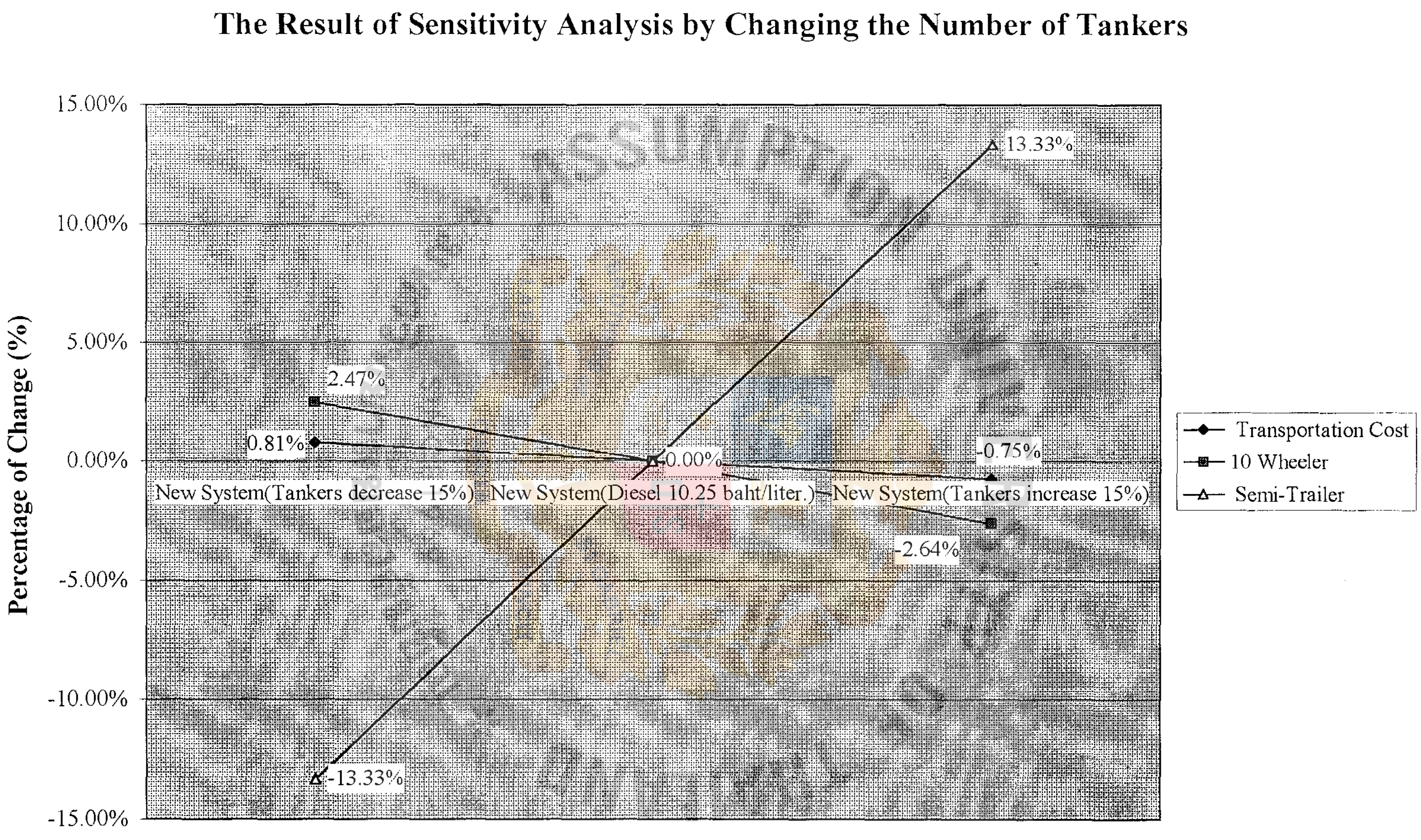


Figure 5.4. The Chart of Sensitivity Analysis by Changing the Number of Tankers.

VI. CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the author divides into 3 parts. The first part is the conclusion of the result that is obtained by research methodology in the last chapter. The second part is the recommendation or the way to develop this project in the future. The third part is the further study.

6.1 Conclusions

According to the transportation system in the present it determines the tankers operate in individual location during working time. It shows that the number of tankers exceeds the necessity that cause the transportation cost to be high. One way that can reduce the transportation cost is determining the optimal number of tankers that they should deliver the oil product to customers located both in Bangkok and upcountry as much as possible. The scope of this project is the transportation gasoline product between Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong. To obtain the optimal number of tankers, there are three steps of the study as follows:

(1) The first step is designing the route model to estimate the number of trips that the tanker can operate per day.

(2) The second step is the formulation of linear programming model of the new transportation system and solving by Lindo programming.

(3) The third step is the calculation of the number of tankers that should be located in Bangkok depot.

The objective function of linear programming model is determining the optimal number of tankers to minimize the transportation cost that consists of the fixed cost and the variable cost. The constraint functions are created by applying the restriction of the existent number of tankers, the number of trips of orders per day that one tanker can operate, and the number of trips or orders per day that each depot operates to deliver the oil product to customers. The result of this analysis shows that the optimal number of 10 wheelers located in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong is 63,4,0,1,12 and 0 respectively. And the number of semi-trailers located in Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong is 0,0,2,2,0, and 12 respectively. The transportation cost is 368,454.46 bahts per day by estimating the diesel price at 10.25 bahts per liter.

According to this method, the company can save the transportation cost about 77,008.98 bahts per day or 17.77% because the number of 10 wheelers reduce 44 or 35.20% of the current system but the number of semi-trailers is equal to the current system.

From the sensitivity analysis of the linear programming model, it can be concluded as follows:

(1) The Change of Cost

When the diesel price changes by 25%, it effects the transportation cost change by 4.68% in the same direction but the number of tankers is still not changed. Moreover, the important summarization about changing of diesel price from the sensitivity analysis shows that the price of diesel changes 1 baht per liter effect the transportation cost change by 1.83% in the same direction.

(2) The Change of Trips or Orders' Number per day

(a) The 15% increase in number of trips or orders per day effect to the transportation cost increase by 16.12% and the number of 10 wheelers increase by 18.52%. However, the number of semi-trailers is still not changed.

(b) The 15% decrease in number of trips or orders per day effect to the transportation cost decrease by 15.44% and the number of 10 wheelers by 16.05%. However, the number of semi-trailers is still not changed.

(3) The Change of the Tankers' Number

(a) The 15% increase in number of tankers to the fleet effect to the transportation cost decrease by 0.75%. The optimal number of 10 wheelers decrease by 2.64% and the optimal number of semi-trailers increase by 13.33%.

(b) The 15% decrease in number of tankers to the fleet effect to the transportation cost increase by 0.81%. The optimum number of 10 wheelers increase by 2.47% and the optimal number of semi-trailers decrease by 13.33%.

6.2 Recommendations

The result of this analysis shows that the new transportation system that has the optimal number of tankers for delivering the oil product to customers in Bangkok, Pathumtanee, Ayuttthaya, Saraburi, Samutsongkhram, and Rayong can be more economical than the current system. Therefore, the company should change the current transportation system to the new transportation system as the principle in this project by doing the following:

(a) The company should allocate the optimal number of tankers located at each depot and control them to gain the number of trips per day as this new transportation system.

(b) Moreover, the authorities who have duty on allocating the tankers to deliver the product to customers have to have the good enough skill and experience.

Finally, the analytical methods in this project can also benefit to other companies with respect to the transportation products to customers located in various sites.

6.3 Further Study

The scope in this study is limited at the transportation between Bangkok, Pathumtanee, Ayutthaya, Saraburi, Samutsongkhram, and Rayong. So, the scope of further study should also extend to the other routes that are used to deliver the oil product to customers in order to gain the most utilization.

Moreover, instead of minimizing the transportation cost, the next study should aim at how to gain the maximum profit and study the other methods that can reduce the transportation cost except the linear programming model such as determining the shortest route of transportation.

APPENDIX A

THE LAND TRANSPORT DEPARTMENT REGULATION

ข้อบังคับเจ้าพนักงานจราจรทั่วราชอาณาจักร
ว่าด้วย การห้ามรถยนต์บรรทุกน้ำมัน ตั้งแต่ 6 ล้อขึ้นไป
และรถพ่วง เดินในเขตกรุงเทพมหานคร พ.ศ. 2542

ตามที่ได้มีข้อบังคับเจ้าพนักงานจราจรทั่วราชอาณาจักร ว่าด้วย การห้ามรถยนต์บรรทุกน้ำมัน ตั้งแต่ 6 ล้อขึ้นไป และรถพ่วง เดินในเขตกรุงเทพมหานคร พ.ศ. 2537 นั้น

เพื่อความสะดวกและปลอดภัยในการจราจร และช่วยลดปัญหาการจราจรที่คับคั่งในเขตกรุงเทพมหานครและปริมณฑล โดยไม่เป็นอุปสรรคกระทบในการประกอบกิจการค้าน้ำมันประเภทต่าง ๆ ผู้บัญชาการตำรวจแห่งชาติ ในฐานะเจ้าพนักงานจราจรทั่วราชอาณาจักร อาศัยอำนาจตามความในมาตรา 139 (1) แห่งพระราชบัญญัติจราจรทางบก พ.ศ. 2522 จึงออกข้อบังคับไว้ดังต่อไปนี้

ข้อ 1 ข้อบังคับนี้เรียกว่า "ข้อบังคับเจ้าพนักงานจราจรทั่วราชอาณาจักร ว่าด้วย การห้ามรถยนต์บรรทุกน้ำมัน ตั้งแต่ 6 ล้อขึ้นไป และรถพ่วงเดินในเขตกรุงเทพมหานคร พ.ศ. 2542"

ข้อ 2 ให้ยกเลิกข้อบังคับเจ้าพนักงานจราจรทั่วราชอาณาจักร ว่าด้วย เปลี่ยนแปลงแก้ไขการห้ามรถยนต์บรรทุกน้ำมัน ตั้งแต่ 6 ล้อขึ้นไป และรถพ่วง เดินในเขตกรุงเทพมหานคร พ.ศ. 2537 ลงวันที่ 30 พฤศจิกายน พ.ศ. 2537

ข้อ 3 การกำหนดห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ตั้งแต่ 6 ล้อขึ้นไปเดินในเขตกรุงเทพมหานคร ให้เป็นไปตามลักษณะหรือชนิดของรถ ดังต่อไปนี้

3.1 ห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิด 6 ล้อ และ 10 ล้อ เดินในเขตกรุงเทพมหานคร ระหว่างเวลา 06.00 - 22.00 น. ทุกวัน เว้นวันหยุดราชการ

3.2 ห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิดกึ่งพ่วงเดินตลอดเวลาทุกวัน ในถนนทุกสายซึ่งอยู่ภายในถนนวงรอบที่ต่อเนื่องดังนี้ ถนนพระรามที่ 3 ถนนสุนทรโกษา ถนนอาจณรงค์ ถนนทางรถไฟสายปากน้ำเดิมตั้งแต่แยกถนนเกษมราษฎร์ ถึงแยกถนนสรรพาวุธ ถนนสรรพาวุธ ถนนบางนา-ตราดตั้งแต่แยกถนนสุขุมวิท ถึงแยกถนนศรีนครินทร์ ถนนศรีนครินทร์ ถนนลาดพร้าวตั้งแต่แยกถนนรามคำแหง ถึงแยกถนนรัชดาภิเษก ถนนรัชดาภิเษกตั้งแต่แยกถนนลาดพร้าว ถึงแยกถนนกรุงเทพ-นนทบุรี ถนนวงศ์สว่าง สะพานพระราม 7 ถนนจรัญสนิทวงศ์ ถนนรัชดาภิเษก (ด้านทิศตะวันตก) และสะพานกรุงเทพ

แต่ผ่อนผันให้รถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิดกึ่งพ่วงเดินได้ในบางถนนซึ่งอยู่ภายในถนนวงรอบดังกล่าว ตั้งแต่เวลา 22.00 - 05.00 น. ของวันรุ่งขึ้นทุกวัน ในถนนดังต่อไปนี้

3.2.1 บนทางพิเศษทุกสาย (ทางด่วน ซึ่งเป็นของการทางพิเศษแห่งประเทศไทยเท่านั้น)

3.2.2 ถนนสาธุประดิษฐ์ ตั้งแต่แยกถนนพระรามที่ 3 ถึงแยกถนนใต้ทางด่วนสาธุประดิษฐ์

3.3 ห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิดกึ่งพ่วงเดินตลอดเวลาทุกวัน ในถนนบางสายที่เป็นถนนวงรอบ ตามข้อ 3.2 ดังต่อไปนี้

3.3.1 ถนนศรีนครินทร์

3.3.2 ถนนลาดพร้าว ตั้งแต่แยกถนนรามคำแหง ถึงแยกถนนรัชดาภิเษก

3.3.3 ถนนรัชดาภิเษก ตั้งแต่แยกถนนลาดพร้าว ถึงแยกถนนกรุงเทพ-นนทบุรี

3.3.4 ถนนบางสะว่าง

3.3.5 สะพานพระราม 7

3.3.6 ถนนจรัญสนิทวงศ์

3.3.7 ถนนรัชดาภิเษก (ด้านทิศตะวันตก)

3.3.8 สะพานกรุงเทพ

3.4 ห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิดกึ่งพ่วงเดินในช่วงเวลาตั้งแต่ 05.00 - 22.00 น. ของทุกวันในถนนบางสายที่เป็นถนนวงรอบ ตามข้อ 3.2 ดังต่อไปนี้

3.4.1 ถนนพระรามที่ 3

3.4.2 ถนนสุนทรโกษา

3.4.3 ถนนอาจณรงค์

3.4.4 ถนนทางรถไฟสายปากน้ำเดิม ตั้งแต่แยกถนนเกษมราษฎร์ ถึงแยกถนนสรรพาวุธ

3.4.5 ถนนสรรพาวุธ

3.4.6 ถนนบางนา-ตราด ตั้งแต่แยกถนนสุขุมวิท ถึงแยกถนนศรีนครินทร์

3.5 ห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิดกึ่งพ่วงเดินตั้งแต่เวลา 06.00 - 22.00 น. ทุกวัน เว้นวันหยุดราชการ ในถนนทุกสายที่อยู่ภายนอกของถนนรอบวงตามข้อ 3.2

3.6 ห้ามรถยนต์บรรทุกน้ำมันเชื้อเพลิง (น้ำมันใส) ชนิดพ่วงสองตอนเดินในเขตกรุงเทพมหานคร ตลอดเวลาทุกวัน ยกเว้นให้เดินได้ระหว่างเวลา 22.00 - 05.00 น. ของวันรุ่งขึ้น ในถนนบางสายในเขตกรุงเทพมหานคร ดังต่อไปนี้

3.6.1 บนทางพิเศษทุกสาย (ทางด่วน ซึ่งเป็นของการทางพิเศษแห่งประเทศไทยเท่านั้น)

3.6.2 ถนนพระรามที่ 3

3.6.3 ถนนสุนทรโกษา

3.6.4 ถนนเกษมราษฎร์ ตั้งแต่แยกกรมศุลกากร ถึง แยกใต้ทางด่วนท่าเรือ 1 และ 2

3.6.5 ถนนอาจณรงค์

3.6.6 ถนนทางรถไฟสายปากน้ำเดิม

3.6.7 ถนนสรรพาวุธ

3.6.8 ถนนสุขุมวิท ตั้งแต่แยกถนนสรรพาวุธ ถึง สุดเขตกรุงเทพมหานคร

3.6.9 ถนนบางนา-ตราด ตั้งแต่แยกถนนสุขุมวิท ถึงสุดเขตกรุงเทพมหานคร

3.6.10 ถนนวงแหวนรอบนอกทุกสายในเขตกรุงเทพมหานคร

3.6.11 ถนนอ่อนนุช และถนนลาดกระบัง ตั้งแต่แยกถนนวงแหวนรอบนอก ถึงสุดเขตกรุงเทพมหานคร

3.6.12 ถนนสุขาภิบาล 3 และถนนสุวินทวงศ์ ตั้งแต่แยกถนนวงแหวนรอบนอก ถึงสุดเขตกรุงเทพมหานคร

3.6.13 ถนนร่มเกล้า

3.6.14 ถนนนิมิตรใหม่

3.6.15 ถนนรามอินทรา

3.6.16 ถนนแจ้งวัฒนะ

3.6.17 ถนนสาธุประดิษฐ์ ตั้งแต่แยกถนนพระรามที่ 3 ถึงแยกใต้ทางด่วน สาธุประดิษฐ์

3.6.18 ถนนพระรามที่ 2

3.6.19 ถนนเอกชัย ตั้งแต่แยกถนนวงแหวนรอบนอก ถึงสุดเขต กรุงเทพมหานคร

3.6.20 ถนนเพชรเกษม ตั้งแต่แยกถนนวงแหวนรอบนอก ถึงสุดเขต กรุงเทพมหานคร

3.6.21 ถนนบรมราชชนนี ตั้งแต่แยกถนนวงแหวนรอบนอก ถึงสุดเขต กรุงเทพมหานคร

ข้อ 4 ห้ามรถยนต์บรรทุกน้ำมันอุตสาหกรรม (น้ำมันเตา) ตั้งแต่ 6 ล้อขึ้นไป และรถพ่วงเดินในเขตกรุงเทพมหานคร ระหว่างเวลา 06.00 - 22.00 น. ทุกวัน เว้นวันหยุดราชการ และในวันราชการให้เดินรถได้ระหว่างเวลา 09.00 - 16.00 น. ในถนนบางสายในเขต กรุงเทพมหานคร ดังต่อไปนี้

4.1 บนทางพิเศษทุกสาย (ทางด่วน ซึ่งเป็นของการทางพิเศษแห่งประเทศไทย เท่านั้น)

4.2 ถนนทางรถไฟสายปากน้ำเดิม ตั้งแต่แยกถนนเกษมราษฎร์ ถึงทางแยก ถนนสรรพาวุธ

4.3 ถนนสรรพาวุธ ตั้งแต่ทางแยกถนนทางรถไฟสายปากน้ำเดิม ถึงแยก ถนนสุขุมวิท

4.4 ถนนสุขุมวิท ตั้งแต่แยกถนนสรรพาวุธ ถึงสุดเขตกรุงเทพมหานคร

4.5 ถนนบางนา-ตราด ตั้งแต่แยกถนนสุขุมวิท ถึงสุดเขตกรุงเทพมหานคร

4.6 ถนนอาจณรงค์

4.7 ถนนเกษมราษฎร์

4.8 ถนนสุนทรโกษา

4.9 ถนนเชื้อเพลิง

4.10 ถนน ณ ระนอง

4.11 ถนนพระรามที่ 3 ตั้งแต่แยกถนนสุนทรโกษา ถึงแม่น้ำเจ้าพระยา

4.12 ถนนนางลิ้นจี่ ตั้งแต่ทางแยกถนนพระรามที่ 3 ถึงแม่น้ำเจ้าพระยา

4.13 สะพานกรุงเทพ

4.14 ถนนมไหศวรรย์

4.15 ถนนสมเด็จพระเจ้าตากสิน ตั้งแต่ทางแยกถนนมไหศวรรย์ ถึงสะพานดาวคะนอง

4.16 สะพานดาวคะนอง

4.17 ถนนสุขสวัสดิ์ ตั้งแต่สะพานดาวคะนอง ถึงสุดเขตกรุงเทพมหานคร

4.18 ถนนธนบุรี-ปากท่อ จากทางแยกถนนสุขสวัสดิ์ ถึงสุดเขตกรุงเทพมหานคร

4.19 ถนนเจริญนคร ตั้งแต่ทางแยกมไหศวรรย์ ถึงถนนราษฎร์บูรณะ

4.20 ถนนราษฎร์บูรณะ ตั้งแต่ถนนเจริญนคร ถึงสุดเขตกรุงเทพมหานคร

4.21 ถนนวงแหวนรอบนอกทุกสาย ในเขตกรุงเทพมหานคร

4.22 ถนนวิภาวดีรังสิต ห้ามมิให้เดินรถระหว่างเวลา 06.00 - 09.00 น. และเวลา 16.00 - 20.00 น.

ข้อ 5 ห้ามรถยนต์บรรทุกน้ำมันประเภทอื่น เช่น น้ำมันหล่อลื่น น้ำมันพืช น้ำยาเคมี น้ำมันดิบ เป็นต้น ตั้งแต่ 6 ล้อขึ้นไป และรถพ่วง เดินในเขตกรุงเทพมหานคร ตั้งแต่เวลา 06.00 - 10.00 น. และเวลา 15.00 - 21.00 น. ของทุกวัน เว้นวันหยุดราชการ

ข้อ 6 ความในข้อ 3, 4 และ ข้อ 5 มิให้ใช้บังคับแก่รถยนต์บรรทุกน้ำมันที่ได้รับหนังสืออนุญาตผ่อนผันจากเจ้าพนักงานจราจร

ข้อ 7 บรรดา ข้อบังคับ ประกาศ ระเบียบใดที่ขัดหรือแย้งกับข้อบังคับนี้ ให้ใช้ข้อบังคับนี้แทน

ข้อ 8 ข้อบังคับนี้ ให้ใช้บังคับตั้งแต่วันถัดจากวันประกาศในราชกิจจานุเบกษาเป็นต้นไป

ประกาศ ณ วันที่ 12 เมษายน พ.ศ. 2542

พลตำรวจเอก [signature]

(ประชา พรหมนอก)

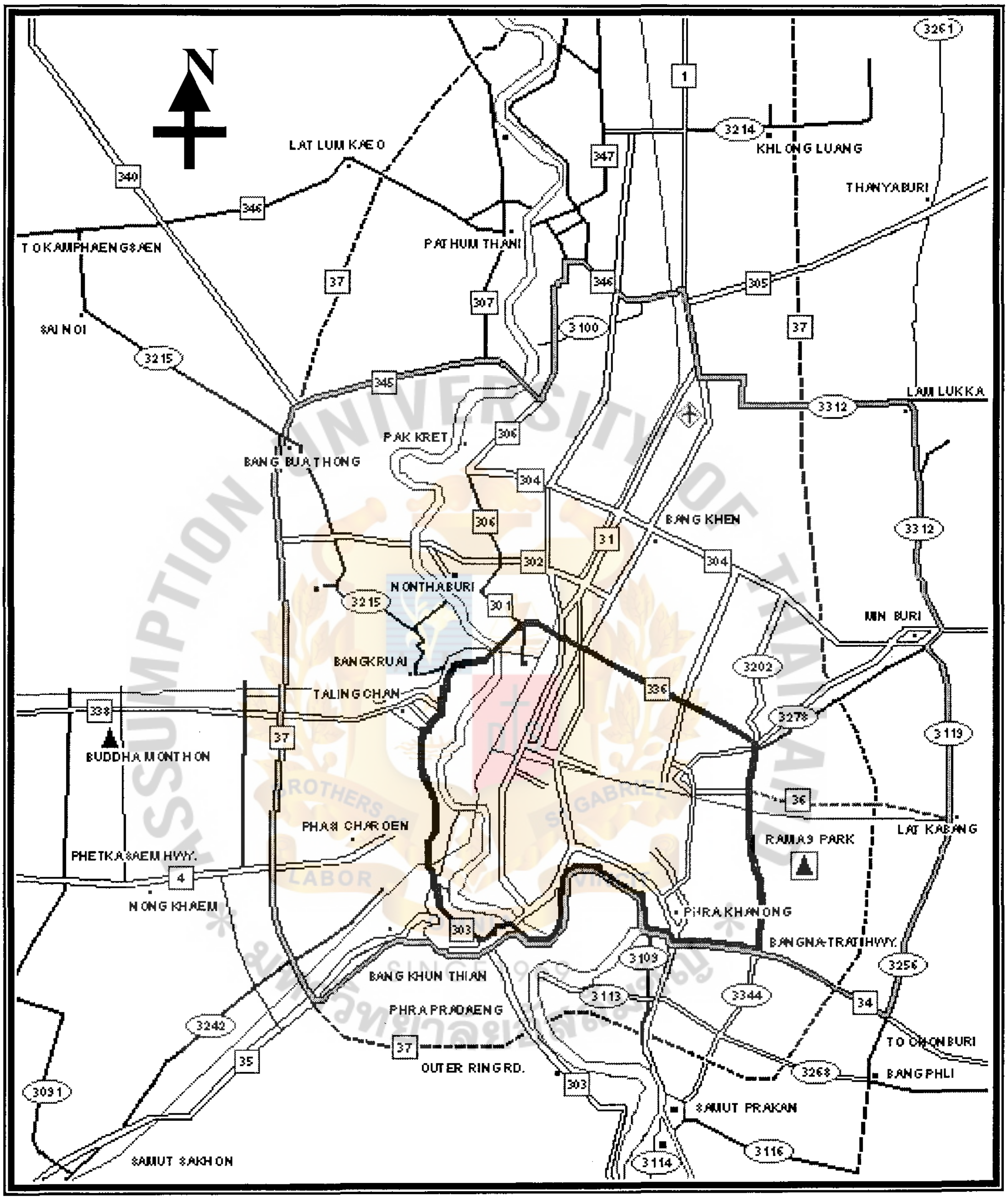
ผู้บัญชาการตำรวจแห่งชาติ

เจ้าพนักงานจราจรทั่วราชอาณาจักร

APPENDIX B

BAN ZONE

BAN ZONE



LARGE TRUCK BAN ZONE

TRUCK BAN ZONE

OUTTER RING

Figure B.1. Ban Zone.

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