

**A SIMULATION OF VEHICLE FLEET MANAGEMENT SYSTEM
FOR NETWORK OF NGV SERVICE STATIONS**



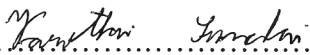
VAROTHAI SUNALAI

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF ENGINEERING
(INDUSTRIAL ENGINEERING)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2010**

COPYRIGHT OF MAHIDOL UNIVERSITY

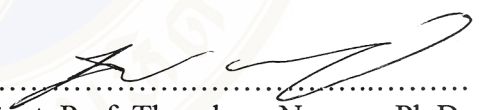
Copyright by Mahidol University

Thesis
entitled
**A SIMULATION OF VEHICLE FLEET MANAGEMENT SYSTEM
FOR NETWORK OF NGV SERVICE STATIONS**

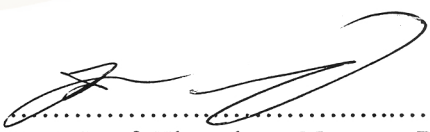

.....
Miss Varothai Sunalai
Candidate


.....
Asst. Prof. Waessara Weerawat, Ph.D.
Major advisor


.....
Assoc. Prof. Duangpun Kritchanchai, Ph.D.
Co-advisor


.....
Asst. Prof. Thanakorn Naenna, Ph.D.
Co-advisor


.....
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies,
Mahidol University


.....
Asst. Prof. Thanakorn Naenna, Ph.D.
Program Director
Master of Engineering Program in
Industrial Engineering
Faculty of Engineering,
Mahidol University

Thesis
entitled
**A SIMULATION OF VEHICLE FLEET MANAGEMENT SYSTEM
FOR NETWORK OF NGV SERVICE STATIONS**

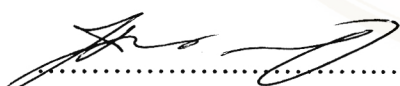
was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Engineering (Industrial Engineering)

on
December 24, 2010

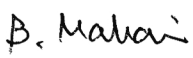

.....
Miss Varothai Sunalai
Candidate

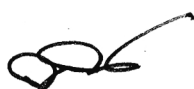

.....
Lect. Chayakrit Charoensiriwath, Ph.D.
Chair


.....
Asst. Prof. Waressara Weerawat, Ph.D.
Member


.....
Asst. Prof. Thanakorn Naenna, Ph.D.
Member


.....
Assoc. Prof. Duangpun Kritchanhai, Ph.D.
Member


.....
Prof. Banchong Mahaisavariya,
M.D., Dip Thai Board of Orthopedics
Dean
Faculty of Graduate Studies,
Mahidol University


.....
Asst. Prof. Rawin Raviwongse, Ph.D.
Dean
Faculty of Engineering,
Mahidol University

ACKNOWLEDGEMENTS

This thesis would not have been possible without help, support and patience of my advisors' team. First and foremost I offer my sincerest gratitude to my professor, Asst. Prof. Waessara Weerawat and Dr. Chayakrit Charoensiriwath, who gave a good guidance for thesis. I am also grateful to my co-advisors, Assoc. Prof. Duangpun Kritchanhai and Asst. Prof. Thanakorn Naenna for advice on how to improve the thesis to be more completely.

I would like to thank also teaching staff but more importantly the Industrial Engineering staff in the Faculty of Engineering, Mahidol University for their kindness and helpful all times when I studied. I thank to my friends for their help and support me along this course.

Finally, this research was financially supported by the Thailand Research Fund (TRF), contract no. MLSC515001.

Varothai Sunalai

A SIMULATION OF VEHICLE FLEET MANAGEMENT SYSTEM FOR NETWORK OF NGV SERVICE STATIONS

VAROTHAI SUNALAI 5036718 EGIE/M

M.Eng. (INDUSTRIAL ENGINEERING)

THESIS ADVISORY COMMITTEE: WARESSARA WEERAWAT, PH.D.,
DUANGPUN KRITCHANCHAI, PH.D, THANAKORN NAENNA, PH.D.,

ABSTRACT

In the study of the NGV transportation system between the main stations and substations, we found problems of gas shortage, early delivery, and delayed delivery at substations due to the trailer fleet delivery management between the main stations and substations. The capacity of each trailer substation is 1-2 trailers. This research aims to determine the reorder point and the number of trailers at the main station to decrease these problems. A simulation is applied in this study. This study has three major steps. The first step is to modify the reorder point calculated from the gas demand and delivery time of each substation. The second step is to determine the optimum number of trailers at the main station by using the number of gas shortage times from the first step. And the final step is to analyze the sensitivity of the reorder point and the number of trailers when gas demand and delivery time change at each substation. The result of modifying the reorder point at main station 1 decreases the number of early deliveries and delayed deliveries at substations. The number of on time deliveries increases. In main station 2, the number of gas shortage times and delayed deliveries decreases. However, the number of early deliveries increases because 80% of the substations of main station 2 have only one trailer. Modification of the number of trailers at main station 1 decreases the number of trailers by 31.43% and the number at main station 2 decreases by 26%. Sensitivity analysis of the reorder point and the number of trailers found that main station 1 can support changes of demand and delivery time if they do not exceed 30% increase. Main station 2 can support the sum of the changes of demand and delivery time if they do not exceed 30% increase.

KEY WORDS: SIMULATION / NGV SERVICE STATION / REORDER POINT /
FLEET MANAGEMENT

98 pages

การจำลองสถานการณ์ระบบบริหารจัดการยานพาหนะสำหรับเครือข่ายสถานีบริการNGV

A SIMULATION OF VEHICLE FLEET MANAGEMENT SYSTEM FOR NETWORK OF NGV SERVICE STATIONS

วโรทัย ศุนาลัย5036718 EGIE/M

วศ.ม. (วิศวกรรมอุตสาหกรรม)

คณะกรรมการที่ปรึกษาวิทยานิพนธ์: วรศรา วีระวัฒน์, Ph.D., ดวงพรรณ กริชชาญชัย, Ph.D., ธนกรณ์ หนาแน่น Ph.D.,

บทคัดย่อ

ในการศึกษาระบบการขนส่งก๊าซ NGV ระหว่างสถานีบริการหลักและสถานีบริการย่อยพบปัญหาการขาดแคลนก๊าซที่สถานีบริการย่อยรวมถึงการขนส่งที่ไปถึงสถานีบริการย่อยก่อนเวลา และการขนส่งที่ไปถึงล่าช้า เกิดจากการบริหารจัดการในการจัดส่งเทอร์เลอร์ระหว่างสถานีบริการหลักและสถานีบริการย่อย โดยในปัจจุบันสถานีบริการย่อยสามารถรองรับเทอร์เลอร์ที่มาจัดส่งได้ 1-2 เทอร์เลอร์ส่งผลให้เกิดการขาดแคลนก๊าซ การขนส่งที่ไปถึงก่อนเวลา และการขนส่งที่ไปถึงล่าช้าที่เกิดขึ้นที่สถานีบริการย่อย ดังนั้นงานวิจัยนี้มีวัตถุประสงค์เพื่อหาจุดสั่งซื้อใหม่และจำนวนเทอร์เลอร์ที่เหมาะสมกับสถานีบริการหลักที่ทำให้ปัญหาข้างต้นลดลง ซึ่งนำการจำลองสถานการณ์มาประยุกต์ใช้ในการวิจัย3 ขั้นตอนหลัก โดยขั้นตอนแรกคือการปรับเปลี่ยนจุดสั่งซื้อใหม่ซึ่งคำนวณจากความต้องการก๊าซและระยะเวลาที่ใช้ในการจัดส่งของแต่ละสถานีบริการย่อย ขั้นตอนที่สองคือการหาจำนวนเทอร์เลอร์ที่ต้องมีที่สถานีบริการหลักโดยใช้ผลของจำนวนครั้งของการขาดแคลนก๊าซจากการปรับเปลี่ยนจุดสั่งซื้อใหม่ที่ได้ในขั้นตอนแรก และ ขั้นตอนสุดท้ายคือการวิเคราะห์ความไวของจุดสั่งซื้อใหม่และจำนวนเทอร์เลอร์ เมื่อมีการปรับเปลี่ยนความต้องการก๊าซและระยะเวลาที่ใช้ในการจัดส่งของแต่ละสถานีบริการย่อย ผลจากการปรับเปลี่ยนจุดสั่งซื้อของสถานีบริการหลัก1คือมีการขนส่งที่ไปถึงสถานีบริการย่อยก่อนเวลาและที่ไปถึงล่าช้าลดลง ส่วนในสถานีบริการหลัก2มีการขาดแคลนก๊าซและการขนส่งที่ไปถึงล่าช้าลดลง แต่การขนส่งที่ไปถึงก่อนเวลาเพิ่มขึ้นเนื่องจากในสถานีบริการหลัก2มีจำนวนสถานีบริการย่อยที่มี 1 เทอร์เลอร์มากกว่า 80 %ของสถานีบริการย่อยทั้งหมด สำหรับการปรับเปลี่ยนจำนวนเทอร์เลอร์ของสถานีบริการหลัก พบว่าในสถานีบริการหลัก1 ใช้เทอร์เลอร์ลดลง 31.43% และสถานีบริการหลัก2 ใช้เทอร์เลอร์ลดลง 26% และในการวิเคราะห์ความไวของจุดสั่งซื้อและจำนวนเทอร์เลอร์ที่ได้ พบว่าสถานีบริการหลัก1สามารถรองรับการเปลี่ยนแปลงของความต้องการและระยะเวลาที่ใช้ในการจัดส่งได้ไม่เกิน แต่ในขณะที่สถานีบริการหลัก2สามารถรองรับการเปลี่ยนแปลงของผลรวมของความต้องการและระยะเวลาที่ใช้ในการจัดส่งที่เปลี่ยนแปลงได้ไม่เกิน 30%

CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
ABSTRACT (ENGLISH)	iv
ABSTRACT (THAI)	v
LIST OF TABLES	viii
LIST OF FIGURES	x
CHAPTER I INTRODUCTION	1
1.1 Background and problem statement	1
1.2 Objectives	5
1.3 Scope of work	5
CHAPTER II BACKGROUND THEORY AND LITERATURE REVIEW	6
2.1 Background theory	6
2.1.1 Type of natural gas transportation	6
2.1.2 Reorder point system	7
2.1.3 Simulation	8
2.2 Literature review	10
CHAPTER III MATERIAL AND METHOD	19
3.1 Research methodology	19
3.2 Research time	22
CHAPTER IV CASE STUDY ON INFORMATION GATHERING	23
4.1 The work process of the main stations and substation	23
4.2 Problem description	29
4.3 Concept Model	37
4.3.1 Input analysis	39
4.3.2 Model description	41
4.4 Verify Model	45
4.5 The analysis of the warm-up period	46
4.6 Validate Model	47

CONTENTS (cont.)

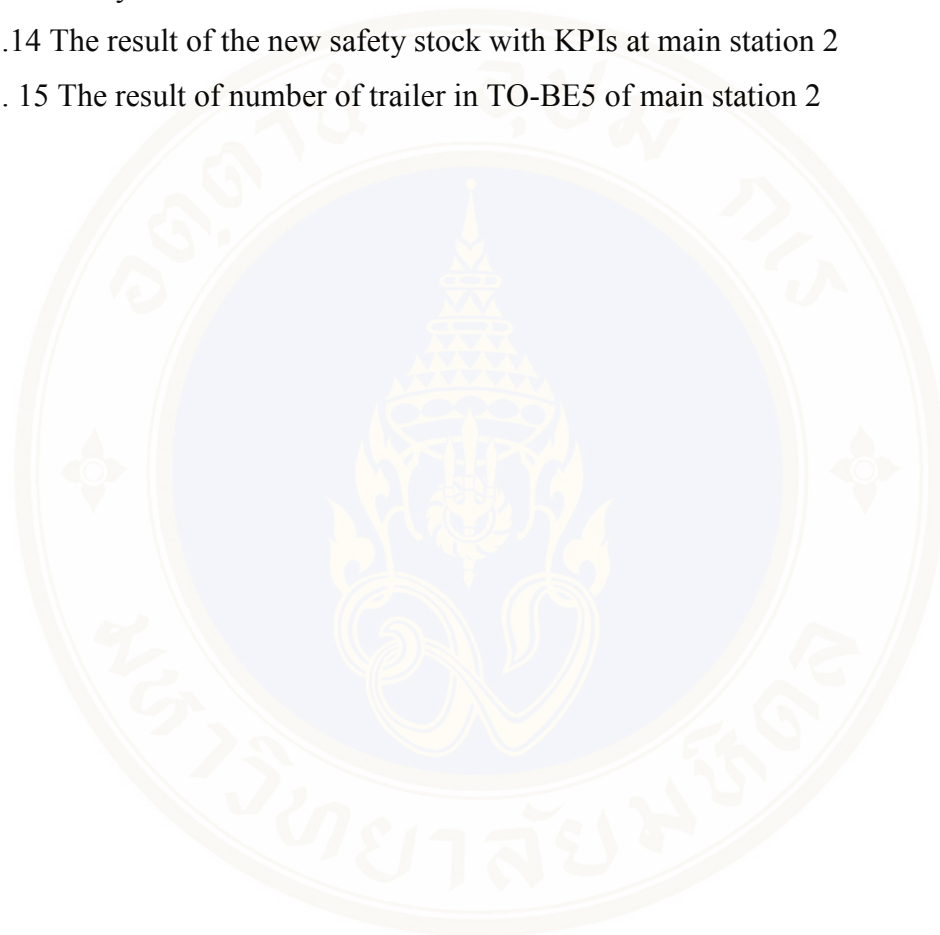
	Page
4.7 The analysis of the number of replications	47
CHAPTER V RESULT	48
5.1 Main station 1	48
5.1.1 The current situation (AS-IS)	48
5.1.2 Adjust reorder point	50
5.1.3 Adjust number of trailer	57
5.1.4 Vary gas demand and delivery time	58
5.2 Main station 2	60
5.2.1 The current situation (AS-IS)	60
5.2.2 Adjust reorder point	61
5.2.3 Adjust number of trailer	70
5.2.4 Vary gas demand and delivery time	71
CHAPTER VI CONCLUSION	72
REFERENCES	75
APPENDICES	77
Appendix A Reduction rate	78
Appendix B Result of 185 replications	92
BIOGRAPHY	98

LIST OF TABLE

Table	Page
2.1 Advantage and disadvantage to use the simulation	9
2.2 Summary of literature review	16
4.1 Substations are responded by main station 1 and main station 2	30
4.2 Capacity of substation	32
4.3 KPIs with function and target	35
4.4 Delivery time with p-value from main station 1 to substation	39
4.5 Delivery time with p-value from main station 2 to substation	39
4.6 Decision variable	40
4.7 Checking variable	40
4.8 Variable for calculated KPI	40
4.9 Attribute	41
4.10 Verify condition	46
5.1 The result of current situation at main station 1 with KPIs	49
5.2 The new reorder point for each substation of main station1	50
5.3 The result of adjusting reorder point each substation with KPIs at main station 1	51
5.4 The new reorder point for each substations of main station 1	55
5.5 The result of the new reorder point for each substation with KPIs at main station 1	56
5.6 The number of trailers of AS-IS in main station 1	57
5.7 The number of trailers of TO-BE4 in main station 1	58
5.8 The result of current situation at main station 2 with KPIs	60
5.9 The new reorder point for each substation of main station 2	62
5.10 The result of adjusting reorder point each substation with KPIs at main station 2	62
5.11 The new reorder point for each substations of main station 2	67
5.12 The result of the new reorder point each substation with KPIs at main station 2	67

LIST OF TABLE (cont.)

Table	Page
5.13 Safety stock for each substation of the main station 2	69
5.14 The result of the new safety stock with KPIs at main station 2	69
5. 15 The result of number of trailer in TO-BE5 of main station 2	70



LIST OF FIGURES

Figure	Page
1.1 The quantity of NGV sold in each year	2
1.2 The operation of the conventional stations	2
1.3 The operation of the main stations	3
1.4 The operation of the substations	3
1.5 The format of NGV transport from the main stations to the substations	4
4.1 The flow of the physical flow and information flow between the main station and substation	24
4.2 The operation of the management department of NGV of the main station	26
4.3 The operation of the production department of the main station	27
4.4 The operation of the transportation department of the main station	28
4.5 The work operation of substation	29
4.6 Concept model with input data	37
4.7 Step of raw data of pressure level to reduction rate	38
4.8 Model from section 1	41
4.9 Model from section 2	42
4.10 Model from section 3	43
4.11 Model from section 4 type 1	44
4.12 Model from section 4 type 2	45
4.13 Graph of inventory number of main station 1 at any time	46
4.14 Graph of inventory number of main station 2 at any time	47
5.1 The result for each substation at main station 1	49
5.2 Comparison number of early deliveries of TO-BE with AS-IS at main station 1	52
5.3 Comparison the number of on time deliveries of TO-BE with AS-IS at main station 1	53

LIST OF FIGURES (cont.)

Figure	Page
5.4 Comparison the number of delayed deliveries of TO-BE with AS-IS at main station 1	54
5.5 Comparison the number of gas shortage times of TO-BE with AS-IS at main station 1	54
5.6 The comparison number of early deliveries and the number of on time deliveries of TO-BE4 with AS-IS at main station 1	56
5.7 The results of modified AS-IS demands and delivery time	59
5.8 The results of modified TO-BE4 demands and delivery time	59
5.9 The result for each substation at main station 2	61
5.10 Comparison the number of early deliveries of TO-BE with AS-IS at main station 2	64
5.11 Comparison the number of on time deliveries of TO-BE with AS-IS at main station 2	64
5.12 Comparison the number of delayed deliveries of TO-BE with AS-IS at main station 2	65
5.13 Comparison the number of gas shortage times of TO-BE with AS-IS at main station 2	66
5.14 Comparison the number of early deliveries and the number of on time deliveries of TO-BE4 with AS-IS at main station 2	68
5.15 The results of TO-BE5 when modified demands and delivery time	71
6.1 The appropriate reorder point for substation with two trailers	72
6.2 The appropriate reorder point for substation with one trailer	73

CHAPTER I

INTRODUCTION

This chapter will discuss four topics: the background and problem statement, the objective, scope of work and expected benefits.

1.1 Background and problem statement

Since the economic and social crisis, the demands for the alternate energy sources have been rapidly increasing. Natural Gas for Vehicles (NGV) is one of the alternative sources which quickly grow during the “Oil price crisis”. There were approximately 1 million NGV cars and 1,350 NGV stations in Pacific Asian Region in 2005. At the present, there are about 2.4 million NGV cars and 1,850 NGV stations. The amount of NGV cars is twice in 5 years.

The policy has been set regarding the trend of NGV usage in Thailand. It requires the extension of NGV usage for transport sector in order to ease the difficult due to increase oil price and pollution issues. Figure 1.1 shows the quantity of NGV sold in each year.

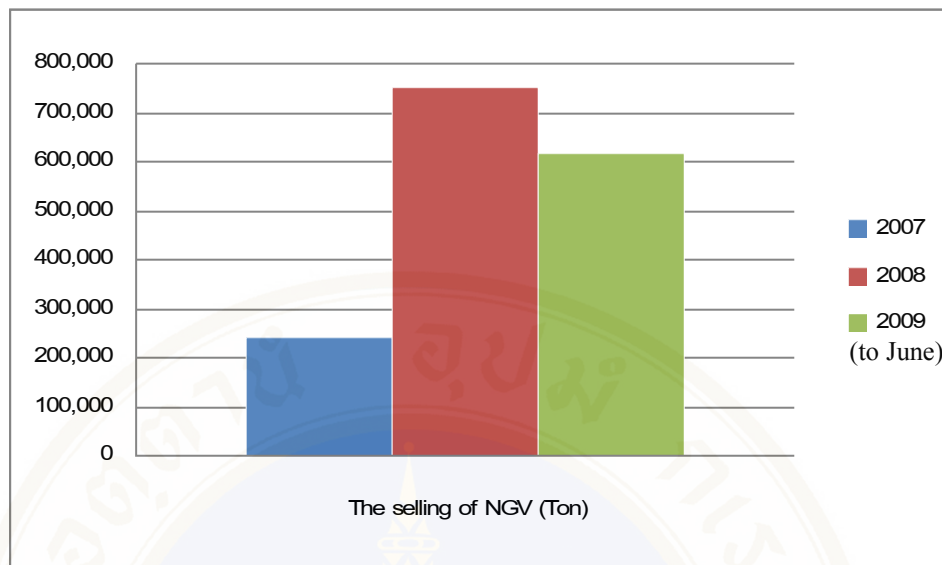


Figure 1.1 The quantity of NGV sold in each year

From the figure 1.1, it shows the amount of the NGV sold and the need of NGV in Thailand which 239,310 tons was sold in 2007 and 750,800 tons in 2008. It was 616,050 tons sold in 2009 (to June) which is 213.74% increasing calculated from 2007 to 2008 and 157.43% increase in 2009 compared to the need in 2007.

Characteristics of NGV station is classified on three types by its operation. (NGV FOCUS, 2007)

1. **Conventional stations** situated around natural gas pipelines area in order to bring the gas from the pipelines to serve directly to customers. It passes the meter system to measure the used gas, go through pressure machine, and then is kept in the gas tank before filling up into the vehicles.

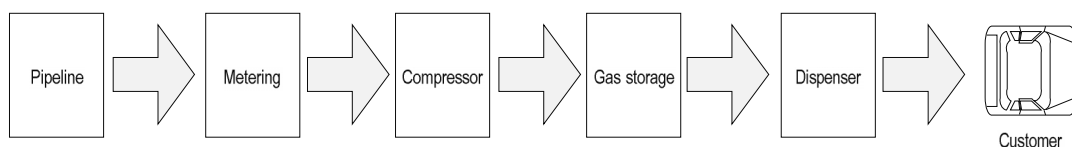


Figure 1.2 The operation of the Conventional stations

2. **Mother stations (main stations)** located in same area as of the conventional stations. However, the compressors at main stations are larger than ones at conventional stations in order to serve the natural gas to daughter stations by trailer.

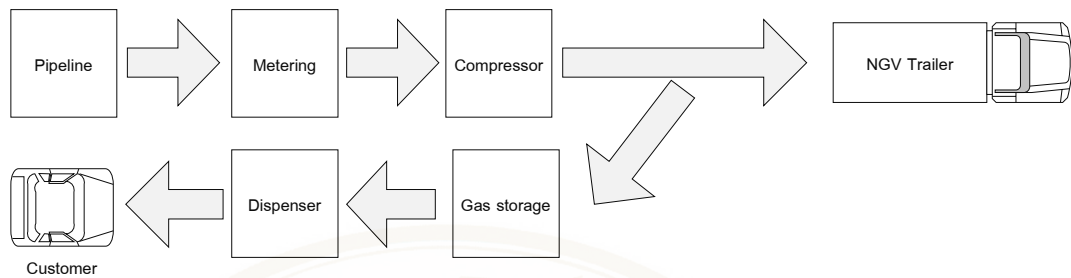


Figure 1.3 The operation of the main stations

3. **Daughter stations (substations)** located at the different the areas from the pipelines. They receive the natural gas from the Main station.

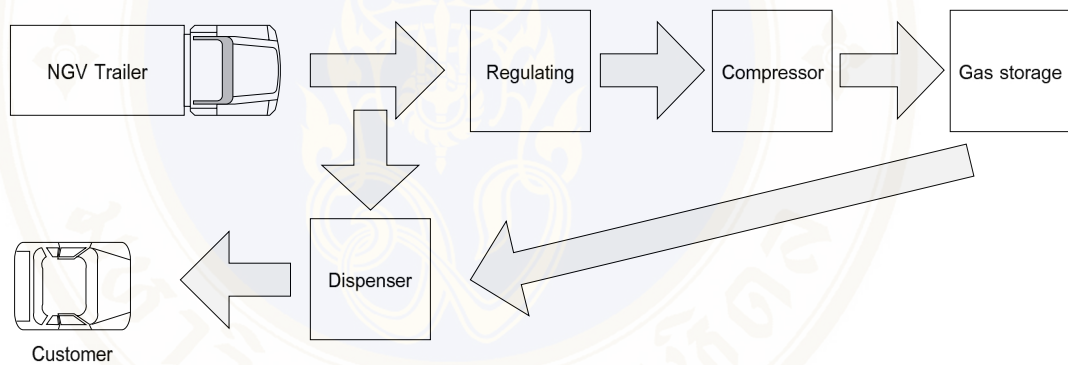


Figure 1.4 The operation of the Substations

NGV is high pressure gas. The trailers filled with NGV are used as storage at the substations. The NGV distribution system in Thailand is classified as Hub and Spokes (Deborah and Morton, 1999) which is shown in the figure 1.5. The main station is classified as Hub while the substations are classified as Spokes. A trailer cycle begins when it is filled with NGV at the main station then serves to the substations. Due to this operation, the main stations attempt to collect many trailers to serve their substations in order to increase their level of service and prevent gas shortage. However, gas shortage still remains at the substations.

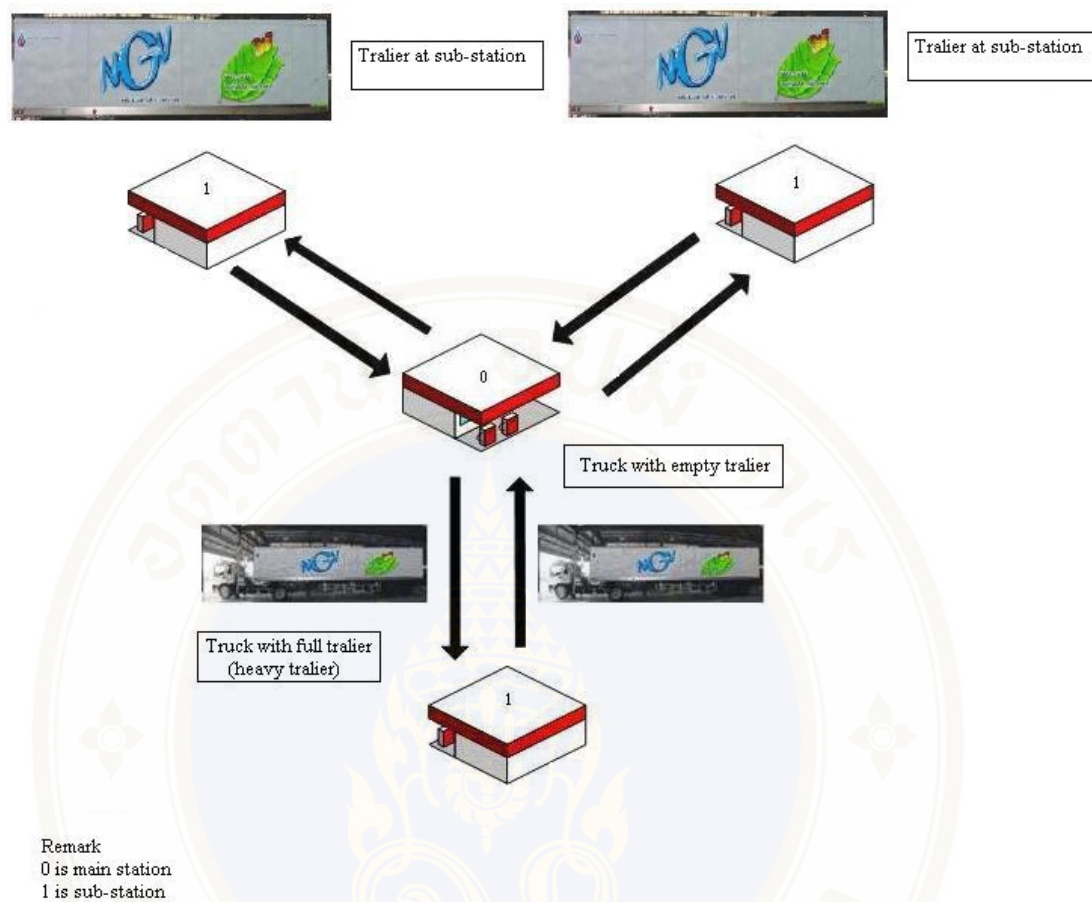


Figure 1.5 The format of NGV transport from the main stations to the substations

A NGV distribution plan is developed by office workers at a main station in each production cycle. They observe gas pressure level in a trailer at the substation and develop a distribution plan by the reorder point criteria. The filled trailers are distributed to substations when their gas pressure is at 1,000 psi of reorder point on subjective level. It causes gas shortage at the substation since it does not consider substation NGV consumption rates and delivery time.

Simulation is the gathering of the various methods that used to simulate the actual circumstance or the behavior of the various systems. The simulation can be used with a very complicated system and the relation cannot be found by writing mathematic conditional equation or the mathematical formula.

In this research, the author aims to determine the reorder point each substation and the number of trailers at the main station. The simulation methods used

are (i) comparison of the reorder point, (ii) calculation the number of trailers, and (iii) sensitivity analysis.

1.2 Objectives

This research proposes new reorder points calculation which are validated and verified by using a new natural gas distribution simulation model. Additionally, a number of trailers will be suggested.

1.3 Scope of work

This study will focus on two main stations. First main station includes fifteen substations and seventy trailers to serve its substation. While second main station contains thirteen substations and fifty trailers to serve its substation. Both main stations are independent. Data is collected during April and May, 2009 for this research.

CHAPTER II

BACKGROUND THEORY AND LITERATURE REVIEW

This chapter will discuss on background theory about type of natural gas transportation, reorder point formulas, and simulation techniques and some related literature about implement simulation technique to real world problem.

2.1 Background Theory

This section will focus on some background theory. Types of natural gas transportation, reorder point formulas, and simulation techniques will be discussed respectively.

2.1.1 Types of natural gas transportation

This section is focused on natural transportation techniques. The types of natural gas transportation are divided by transported natural gas phases. Nowadays, there are three phases to transport: gas, liquid, and solid. In the gas phase, the natural gas is distributed by pipeline and trailer transportations. The pipeline transportations are appropriate with distances up to 7,600 kilometers, and the trailer ones are suitable for distances less than 2,700 kilometers. For liquid phase, the natural gas is transported by special type of trailers which is appropriate with distance in excess of 7,600 kilometers. This phase is aimed to decrease volume of gas, and used for offshore transport. In this case, the natural gas is transported by ships, but it is not popular because of high operational costs. (Najibi et al., 2009)

In Thailand, natural gas is imported by gas pipelines from Burma and Rayong province. Since the gas pipelines are not covered all areas in Thailand, gas is compressed at main stations which are connected to the gas pipelines and transported by truck to Substations.

2.1.2 Reorder point system

Reorder point system is a process to calculate the stock in order to prevent shortage and remain good level of service. Reorder point system can be defined into two categories.

1. Fixed order quantity system: the same constant amount is ordered every time. Any variation in demand is overcome by changing the time between orders. (Kostic, 2009)

2. Fixed order period system: the orders are placed at fixed intervals regardless of the size of the stock. Any variation in demand is overcome by changing the size of the order. (Kostic, 2009)

A calculation of reorder point in Fixed order quantity system from statistic assumption by coefficient data is normal distribution. The calculation can be separated into 3 methods.

1. The uncertainly demand but leading time is constant, formula as following.

$$ROP = (\bar{d} \times LT) + Z\sigma_d\sqrt{LT} \quad \dots\dots\dots(2.1)$$

2. The demand is constant but uncertain leading time, formula as following.

$$ROP = (d \times \overline{LT}) + Z\sigma_{LT}d \quad \dots\dots\dots(2.2)$$

3. The demand and leading time is uncertain, formula as following.

$$ROP = (\bar{d} \times \overline{LT}) + Z\sqrt{\sigma_d^2\overline{LT} + \sigma_{LT}^2\bar{d}^2} \quad \dots\dots\dots(2.3)$$

where

$\bar{d}$	represents a usage rate per the average time unit
LT	represents delivery time
Z	represents a standard value under the service specified of the normal distribution
σ_d	represents a standard deviation of the usage rate per the time unit
$\overline{LT}$	represents average delivery time
σ_{LT}	represents a standard deviation of the delivery time

In this research, natural gas is compressed at main stations and transported to substations with uncertain leading time and demand thus the third formula will be discussed. However, customer demands at Substations cannot be assessed. They are estimated from gas consumption rates. Due to large sufficient number of leading time and consumption rates, they are assumed to be common because of the central limitation.

2.1.3 Simulation

Simulation is the gathering of the various methods used to simulate the actual circumstance or the behavior of the various systems in order to study the flowing of the activity in the various format. (Kelton et al., 2007)

The simulation can be classified into 3 types as follows.

1. Static and Dynamics

1.1 Static is the incident in the system. It always remains the same.

1.2 Dynamic is the change of time which is important and affects the various incidents or the interesting variable.

2. Continuous and Discrete

2.1 Continuous is the format of the system. It is changeable continuously

2.2 Discrete is the format of the system. It is changeable at any point of the time with the probability as a factor

3. Deterministic and Stochastic

3.1 Deterministic is the incident happening under the certain rules and there is definite time specification.

3.2 Stochastic is the incident happening in the uncertain way and there is no fixed rule.

Table 2.1 Advantage and disadvantage for the use of Simulation (Source: Roongrat, 2003)

Advantage	Disadvantage
1. The simulation can be used with a very complicated system and the relation cannot be found in writing mathematic conditional equation or the mathematical formula. 2. The simulation can be created to forecast the future system by using short processing time. 3. The simulation can be used with the all system that cannot be tested on the real situation.	1. It is a must to use the experienced personal regarding program usage and statistics. Thus he can analyze and utilize the result received from the simulation to improve the process. The persons must have a very good understanding of the system. There is already previous collection of the correct data so that the simulation is close to the reality. 2. The result might not be the best choice for the system as it is created by one person. 3. The result is often the estimate.

2.1.3.1 The simulation process

The simulation process will be related to the mathematic principle which will be simulated through the computer as follows. (Kelton et al., 2007)

1. The problem must be specified and solve accordingly with correct method. It is important that one is able to recognize it comprehensively.
2. The objective and scope of the education must be specified clearly.
3. The data is collected from related systems to use it as Input in the Simulation.
4. The simulation must be able to explain the work of the system.
5. The validity must be verified for the model's performance
6. The validity of the simulation is verified in order to check for correct result. It is done by comparing the result with actual work system.
7. The test is planned out by using simulation to cover the analysis of the run round, number of times for the run and the time used for warm-up (in the case the system is steady state)

8. Let the model and the result analysis to be the process using the simulation that has been created to work. Then, analyze according to the plan including the analysis to improve the model when the work system has been changed.

9. The operation manual and report are to be produced when completing the program writing process. The restriction in using those programs must be also identified in the manual.

10. The result must be utilized and considered in any decision making process.

2.1.3.2 Input analysis

The input analysis is to analyze the distribution of input data for using in the model. The distribution of input data is fitted by goodness-of-fit hypothesis tests. The goodness-of-fit hypothesis tests are often used the chi-square and Kolomogorov-Smirnov (K-S) (Kelton et al., 2007). The K-S is nonparametric test. The K-S is suitable for continuous probability distribution. Both of goodness-of-fit hypothesis tests will accept when p-value of chi-square is greater than 0.05 and p-value of K-S is greater than 0.10.

2.1.3.3 Output analysis

The output analysis uses for model validation, and warm-up period calculation. The output analysis bases on statistical method include analysis of pair data. These analyses considered only one set of population, and two observations are made on each individual. The results are shown in a pairing observation: (X_i, Y_i) where $i = 1, \dots, n$ with $E(X_i) = \mu_1$ and $E(Y_i) = \mu_2$.

In testing hypotheses about the different between two means, D_i s are the different within pairs and they are equal to $X_i - Y_i$ with $E(D_i) = E(X_i - Y_i) = \mu_1 - \mu_2$. The pair observations become one sample with normal distribution. The one sample t-test is used to test the hypotheses.

The null hypothesis: $H_0: \mu_D = \Delta_0$

Test statistic value: $t = \frac{\bar{d} - \Delta_0}{s_d / \sqrt{n}}$

Alternate hypothesis	Rejection region
$H_a: \mu_D > \Delta_0$	$t \geq t_{\alpha, n-1}$
$H_a: \mu_D < \Delta_0$	$t \leq -t_{\alpha, n-1}$
$H_a: \mu_D \neq \Delta_0$	$t \leq -t_{\alpha/2, n-1} \text{ or } t \geq t_{\alpha/2, n-1}$

Notation

Δ_0 = null value

μ_D = expected value of D_i s

$\bar{d}$ = sample average of D_i s

s_d = sample standard deviation of D_i s

n = number of sample

α = significant level

2.2 Literature review

Simulation is a technique to analyze and predict the performance of systems (Kim et al., 1997). Nowadays, simulation techniques can be applied in many contents such as optimization, safety engineer, and training education. This section discuss on some related literature about an implementation of simulation model in real world problem.

Kim et al. (1997) purposed an ordering of simultaneous events in distributed discrete event systems specification model or DEVS simulation model. The main purpose of the model was to order the simultaneous events with respect to their fundamental relationship which was similar to the ordering as in sequential DEVS simulation. Due to provide the same result with sequential DEVS simulation, the tie-breaking rule was added. However, the time-and-priority-stamp and ε -delay was developed due to well-defined mechanism. Firstly, the time-and-priority-stamp was developed because of practical the formalism's select function for ordering the events. Then the ε -delay was added to the time-and-priority-stamp for implement the level of an event and represent the fundamental relation of each event.

Dogan et al. (1997) purposed a simulation model in a hardwood sawmill industry. The research was divided into two parts: modeling and analysis, modification and expansion model. The main objective of the research as follows: develop a simulation and animation model, use simulation model to determine the effect of resource allocation, determine the effect of a forklift, improve grade recovery and maximizing profit. The process began when a log was cut into several boards. Then they were made square and sorted. Seven different types of data were required to develop a simulation model as follow: material characteristic distribution, processing time, set up time, downtime, process flow probability, material divergence distribution, and conveyor speeds and capacities. The model was validated against output by grade of board, downtime percentages, and material characteristic distribution. By developing the simulation model, a decision maker could understand and experiment with sawmill system without interrupting the production as well.

Rizzoli et al. (2002) purposed a simulation tool for combined rail/road transport in intermodal terminals. This research concerned about an interface of the terminal with the external. The transportation network in this research was consisted of four nodes: initial intermodal terminal unit, Terminal 1, Terminal 2, and destination intermodal terminal unit and three arcs. The first arc connected between initial intermodal terminal unit and Terminal 1. It was managed by a forwarding company using truck fleet. The second arc connected between Terminal 1 and Terminal 2. It was managed by railway companies. The last arc connected between Terminal 2 and destination intermodal terminal unit. It was managed by a forwarding company again. The train arrivals were defined by timetabling while the truck arrivals could be either statistically model or deterministic input. An experiment was divided into three scenarios: alternative 0, alternative 1, and alternative 2. The alternative 0 was current management practice. The alternative 1 was the implement of computer aided management tools. The alternative 2 was the improvement of the crane equipment. These three scenarios were compared by three factors: road gate processing time, average truck waiting time at the road gate, and mean residence time of intermodal terminal unit as well.

Chen et al. (2002) purposed a simulation study of logistics activities in a chemical plant. The plant produced three different types of products with a fixed

quantity. The products were transported by railways and trucks. The products were kept at several silos and waited for load. The truck and railway arrivals were assumed as Poisson processes. The breakdown time and the time requirement to fix a machine were assumed as a Weibull distribution. The objective of the simulation model was to ensure the process configuration and capacity that could be support continuous flow of the production. The decision variables were not only selection of silos with different sizes but also the combination. The model was validated by historical data, face validity, extreme condition tests, internal validity, and trace as well.

Zhang, C., & Zhang, C. (2007) purposed a design and simulation of demand information sharing in a supply chain. The simulation model was developed for demand information sharing in a three-tier supply chain which consisted of retailer, distributor, and supplier. Activities included receiving orders, receiving shipment from supplier, fulfilling orders, calculating inventories and backlogs, forecasting demands, placing orders, and expecting shipments to arrive in the future. The model was validated by fill rate and average inventories. The first scenario was about sequential order. The retailers placed order to the distributors and they placed the order to the suppliers. The second scenario was about two-tier supply chain. The retailers placed order to the suppliers while the distributors were classified as allocation centers. The third scenario was about no information sharing. The four variables were considered to justify these scenarios: demand variance, demand correlation, demand covariance, distributor location. The result showed that if high demand variance, correlation and variance then the supply chain without intermediate tier would be better.

Meignan et al. (2007) purposed a simulation model and evaluation of urban bus network using a multi-agent approach. The simulation had three major concerns. First, the public transportation characteristic must be included. Second, the simulation could be faster or slower than the real time to virtualize the evolution of the different system components. The bus network was consisted of four agents: itinerary, line, bus stop and bus station. An itinerary expressed a path on the road network. A group of itinerary was a line. A couple of bus stop was connected by an itinerary. A set of bus stop was called a bus station. A measurement of passenger load and a measurement of bus passenger waiting time were shown as results. The measurement of passenger load expressed overload and unused buses thus these could be used to

solved load problems. The measurement of bus passenger waiting time was the measurement the bus network from the passengers' point of view. In addition, there were many key performance indicators to measure an effectiveness of bus network such as the lack of passenger on bus stops so the multi-agent simulation tools could be used to improve the bus network as well.

Cortes et al. (2007) purposed a simulation of freight traffic in the Seville inland port. The scope of the simulation model was covered the freight transportation process through the estuary until to the port including load and unload process. The vessels that arrived to the port were dependent. Result analyses were divided into two parts: Independent traffic analysis and Real traffic analysis. The independent traffic analysis considered traffic with different vessels but each vessel were independent. This analysis considered one vessel arrival per dock so there was no queue at the dock. The real traffic analysis considered queues analysis and maximum value for the vessel system time. According to the analysis, it concluded that the port could be served the current circumstance. However, it might have a traffic problem if it has a difficulty in the container traffic.

Ottman et al. (1999) has studied the international airport of Louisville in order to create the simulation used in the analysis of the running on the parking spacing each day and the running up process of UPS (United Parcel Service) airline. This simulation will make the planner to use in the change of the outgoing flight schedule of the airline by emphasizing at the taxiing time on the airport and the time used at the ramp as much as possible.

David et al. (2002) uses the technique in designing the simulation and the encryption that is efficient and clear by using the simulation of commercial airline and the military air transport process.

Aykapop (2002) has studied the process of transporting the goods of one soda factory. When considered the process, factor and the various defects it is found that there should be the creation of the work system or the simulation in the part of the process in delivering the goods in order to be the standard and the process that is the plan. The summary received is that the simulation can reduce the mistake and help reduce the work time and it can be used to be a way in the transport management and it is a system that supports the decision-making greatly.

Wijitra (2002) has developed the system managing the car schedule time by computer in order to send the goods in a full car from the factory to the various goods distribution center by splitting into 3 minor parts. The first part is to find the appropriate size of the truck and the amount of the goods to be delivered by considering the restrictions in accessing the goods distribution center, the distance of the factory and the type of the goods. Second part is the prioritizing of the goods transport by using Genetic Algorithm in finding the answer with the Tabu search method. The third part is the assignment of the work to the driving personnel. The conclusion is that the schedule of the vehicle scheduling by the simulation has a close result to the received information from the actual work operation and it can reduce the time in the work of the personnel.

Nicholas et al. (2003) has created the simulation in the oil transport by oil transport vessel which must transport the oil for 6 types to 3 locations. The target of this study is to find the numbers of the oil transport vessel that is sufficient to the need of the oil nowadays by using AREANA and OptQuest in the analysis.

Jian et al. (2002) has conducted a research by simulating in the comparison of the transport policy in the various situation in order to find the most appropriate policy for the transport by using the perspective of mix integer programming by finding the optimization point of the two policy in order to compare with each other in the offline system which is another format of the research work with the comparison of the policy of the transport problem which has index as the time that the work is complete and the expense in the travel and the amount of the rejected work.

Chaiwit et al. (2007) has conducted the research by simulating the way of transporting lime bag in order to find the place to store the inventory goods which has compared the work nowadays and the new simulations that has increased in the inventory in order to find the appropriate route in transporting lime bag by using the index as percentage in transporting the goods in time, the overall expense and the average time spent in transporting the lime bag, the percentage of the various uses of the transport vehicles at the factory.

Papier F. and Thonemann U. W. (2008) has focused on managing capacity in rental system. This study has aimed to improve a fleet optimization problem in rental system, so new queuing models have been developed. The developed queuing

models included profit function and derived several structural results. Based on these structural results, this study can show how the fleet size can be optimized, how the fleet structure can be optimized, and how a joint fleet of owned and leased cars can be optimized well. However, some optimal methods are difficult implementation, so an approximation have been developed and tested. The result gives an approximation formula and benefit to who are decision makers of related rental businesses as easily improving profits through these optimizing methods.

The summary of literature reviews is shown in table 2.2.

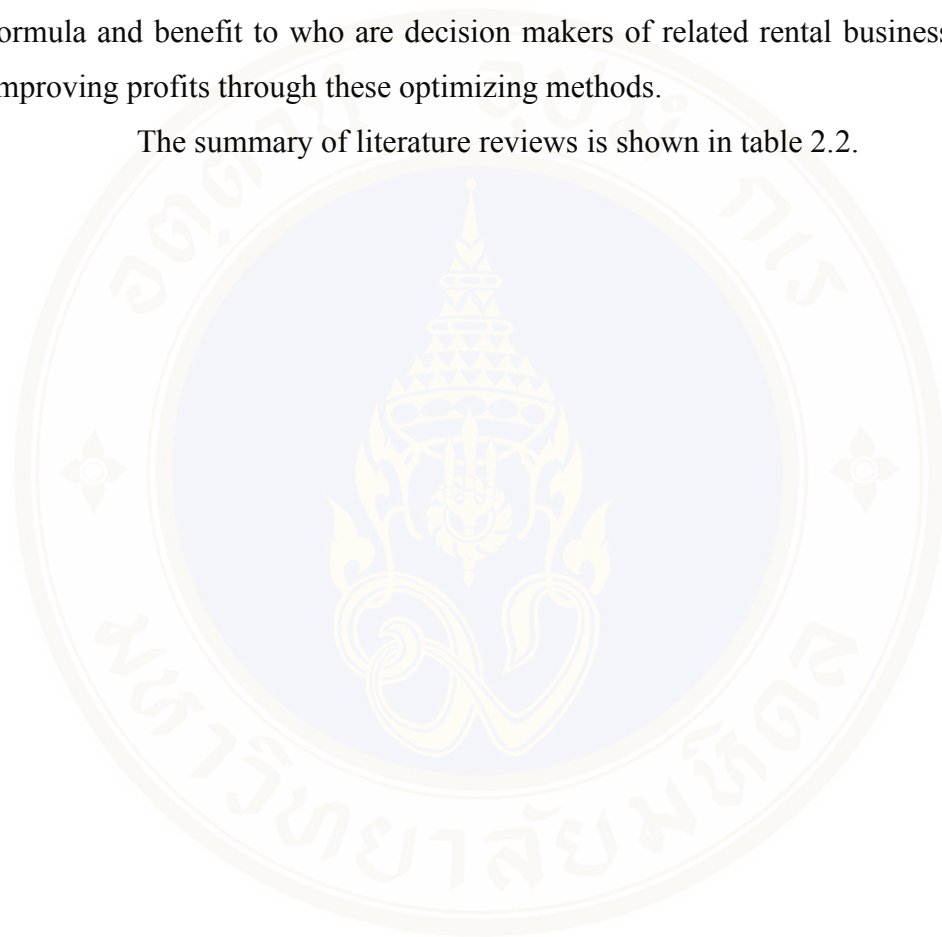


Table 2.2 Summary of literature review

Author	Field	Case study	Remark
Kim et al. (1997)	Production	-	A simulation for determined reorder point when time and priority change
Dogan et al. (1997)	Production	Hardwood sawmill industry	The step of simulation method
Rizzoli et al. (2002)	Transportation	Combined rail/road transport in intermodal terminals.	The step for analysis situation by key performance indicators
Chen et al. (2002)	Production	Chemical plant	The step for validation model
Zhang, C., & Zhang, C. (2007)	Transportation	-	Input data for using in model
Meignan et al. (2007)	Transportation	Urban bus network	Input data for using in model
Cortes et al. (2007)	Transportation	Freight traffic in the Seville inland port	The transportation performance indicators
Ottman et al. (1999)	Transportation	UPS Airline	The concept for Hub and spoke transportation modeling
David et al. (2002)	Transportation	Airline and marine transportation	The concept for Hub and spoke transportation modeling

Table 2.2 The summary of literature review (cont.)

Author	Field	Case study	Remark
Aykapop (2002)	Transportation	Soft drink factory	A simulation for the standardize and effective procedures improvement
Wijitra (2002)	Transportation	Soft drinks	A simulation for goods transport truck schedule
Nicholas et al. (2003)	Transportation	Fuel transportation	This literature is similar to this research but they determined reorder point for each station by Optquest. They assigned the highest and lowest of reorder point for each station. Then analyzed the number of boats required for delivery.
Jian et al. (2002)	Transportation	-	They used a simulation for scenario comparison by keyperformance indicators.
Chaiwit et al. (2007)	Transportation	Cement bag	The transportation performance indicators such as the percent of on time delivery, the average delivery time, and truck utilization
Papier F. and Thonemann U. W. (2008)	Transportation	Cargo rental system	A fleet optimization problem in rental system

CHAPTER III

MATERIAL AND METHOD

This chapter will discuss about research methodology and research time.

3.1 Research methodology

This research applied the simulation method. The research methodology has 8 steps.

3.1.1 Study and state background problem

This step is to study the current transportation system of NGV in order to find the location and point of the problem.

3.1.2 Study background theory and literature

This step is to study the theory and the related literature used to solve the problem.

3.1.3 State scope and objectives used in the research

This step is to state the scope for the frame of the problem and the objectives in order to answer the question of the problem.

3.1.4 State assumption and key performance indicators

This step is to specify assumption in order to know the efficiency in the work of the model and key performance indicators used in the model

3.1.5 Collect information

This step is to collect the necessary information to execute the simulation model.

3.1.5.1 The number of the trailer that can be placed at the substations

3.1.5.2 The reduction of NGV each substation for analyze the demand of NGV

3.1.5.3 The travel time used in the transport of NGV gas from the main stations to the substation

3.1.5.4 The amount of available Compressor and the bay at the main stations

3.1.5.5 The time spent in filling up NGV gas into the trailer

3.1.6 Develop the simulation model

Development of the simulation model includes four procedures. First, the NGV transportation process which is gathered from the first step is analyzed. Second, the model is verified with the NGV process. Finally, the information from step 3.1.5 is input in the model to validate the model as well.

3.1.6.1 To analyze simulation time

3.1.6.2 To create the model by using data from the analysis and the data collected

3.1.6.3 To verify the model whether it works or not

3.1.6.4 To calculate the number of replications, the warm-up time and amounts of times the program is run by using Half-width.

$$n \cong n_o \frac{h_o^2}{h^2}$$

Specified

n = number of replication

n_o = number of test replication

h_o = Half Width from test replication

h = Expected Half Width

3.1.6.5 To validate the model whether the result received from the model has the circumstance closer to the virtual system by using paired T-test

3.1.7 Analyze result and discussion

This step is to compare the amount missing NGV gas nowadays in the policy in ordering gas received from creating the model in the same amount of the vehicles transporting NGV gas. Then, we summarize the appropriate amount of the vehicles and the policy in ordering gas of the sub-station and to propose the way in developing the model in the future

3.1.7.1 Let the model works and examine the result of current scenario, and then change reorder point by using reorder point formula in topic 2.1.2 as follow.

1. The uncertainly demand but lead time is constant, formula as following.

$$ROP = (\bar{d} \times LT) + Z\sigma_d\sqrt{LT}$$

2. The demand and lead time is uncertainly, formula as following.

$$ROP = (\bar{d} \times \overline{LT}) + Z\sqrt{\sigma_d^2\overline{LT} + \sigma_{LT}^2\bar{d}^2}$$

Specified

$\bar{d}$ represents the usage rate per the average time unit

LT represents the delivery time

Z represents the standard value under the service specified of the normal distribution

σ_d represents the standard deviation of the usage rate per the time unit

$\overline{LT}$ represents the average delivery time

σ_{LT} represents the standard deviation of the delivery time

3.1.7.2 To compare the result and use the result from reorder point scenarios to analyze the appropriate amount of the Trailer at main station

3.1.7.3 Use the received result from optimal trailer to analyze sensibility when demand has change, and compare the current result and the best result from model.

3.1.8 Write a full report

After analyze the address questions, we will conclude and make complete report as well.

3.2 Research Time

Research Plan	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1. To study and state background problem												
2. To study background theory and literature												
3. To state scope and objectives used in the research												
4. To state assumption and key performance indicators												
5. To collect information												
6. To develop the simulation model												
7. To analyze result and discussion												
8. To write a full report												

CHAPTER IV

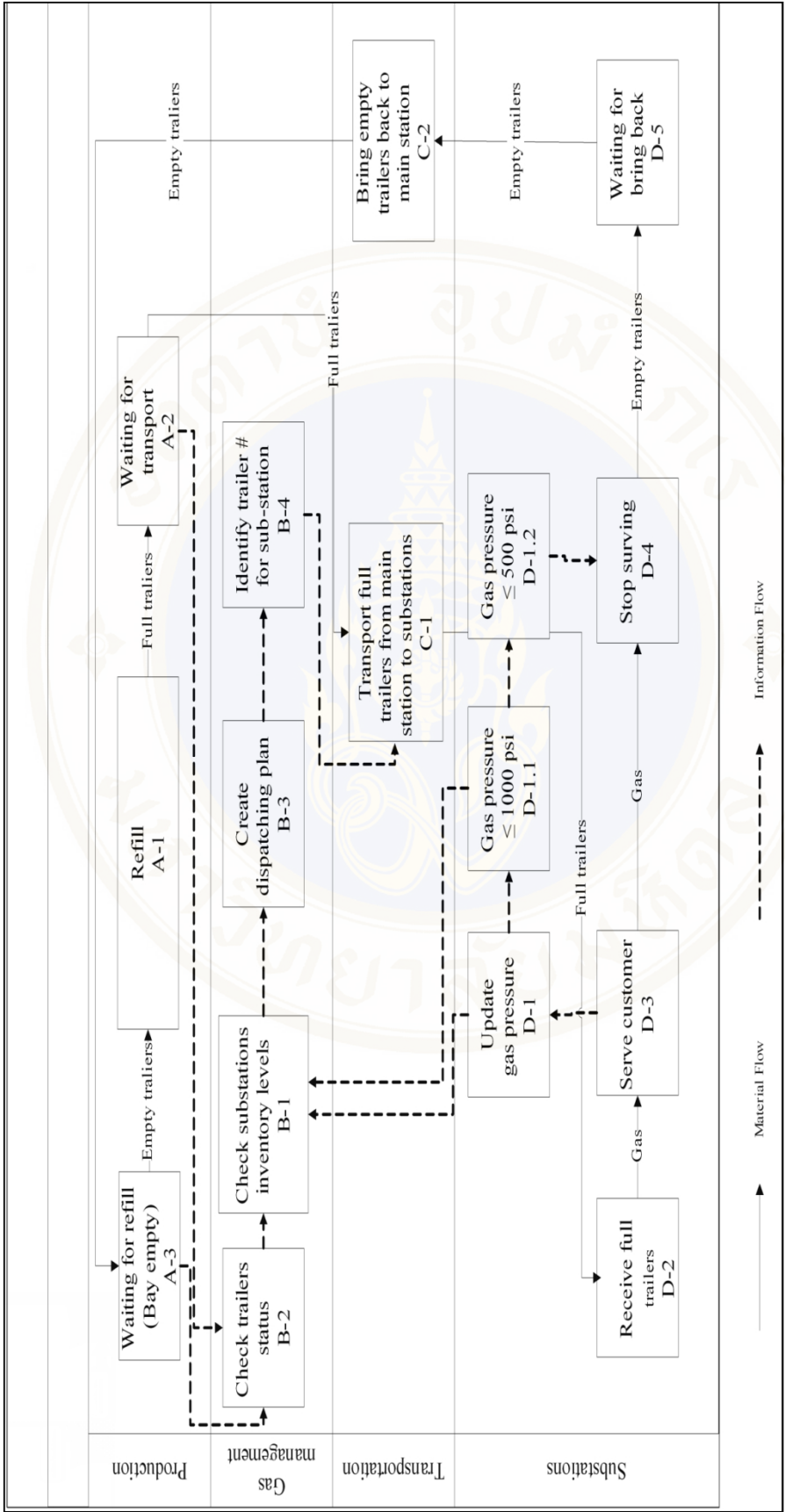
CASE STUDY ON INFORMATION GATHERING

4.1 The work process of the main station and the substation

The operation processes of trailer transportation system were divided into four parts.

1. Production
2. Gas management
3. Transportation
4. Substation

First three parts were operated in the main station. The figure 4.1 will show information flow and material flow.



*pound per square inch (psi)

Figure 4.1 the physical flow and information flow between the main station and substation

The operation process of the main stations will be divided into 3 categories as follows.

1. Production department is responsible for refilling NGV in to the trailer. The process begins with the Trailer being brought into the bay [A-3] to refill NGV [A-1] and when it is done, the trailer (heavy trailer) [A-2] is to deliver the gas to the substations. As shown in figure 4.2.

The main station has different the containing time and the number of compressors. In main station 1 has the containing time at 150 minutes for 12 trailers and 8 compressors. In main station 2, the containing time and the number of compressors are three types; (i) the containing time at 110 minutes for 3 trailers and 4 compressors, (ii) the containing time at 120 minutes for 2 trailers and 4 compressors, and (iii) the containing time at 240 minutes for 4 trailers and 3 compressors.

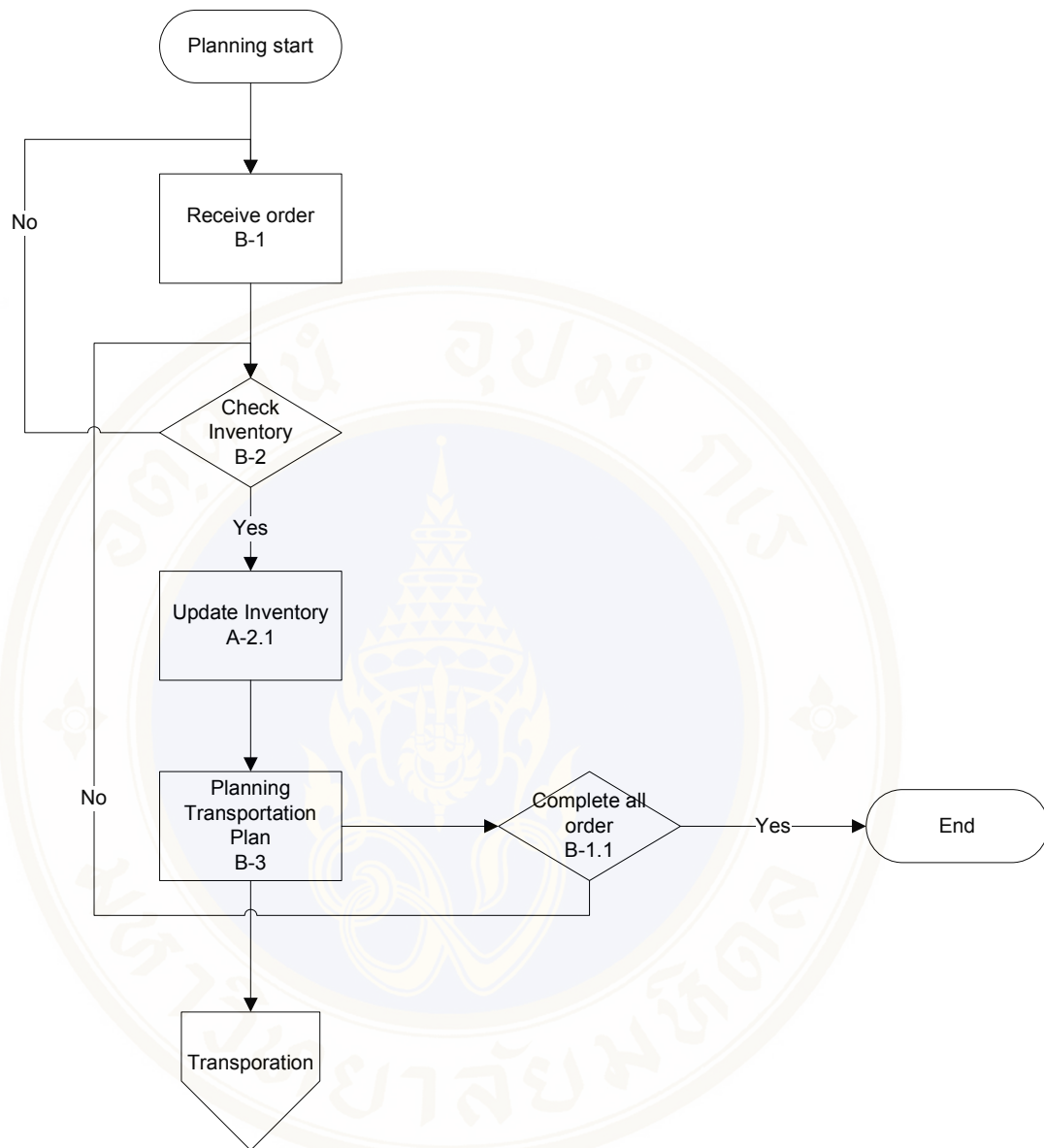


Figure 4.2 the operation of the management department of NGV of the main station

2. The gas management department will check the state of trailer [B-2] and the substation for delivery [B-1] (pressure level in the trailer for substation is 1000 psi). After that they will plan which substation should be delivered (to rearrange order for deliver in the FIFO system, any substation that has run out will be delivered first) and to specify trailer to substation [B-4]. As shown in figure 4.3.

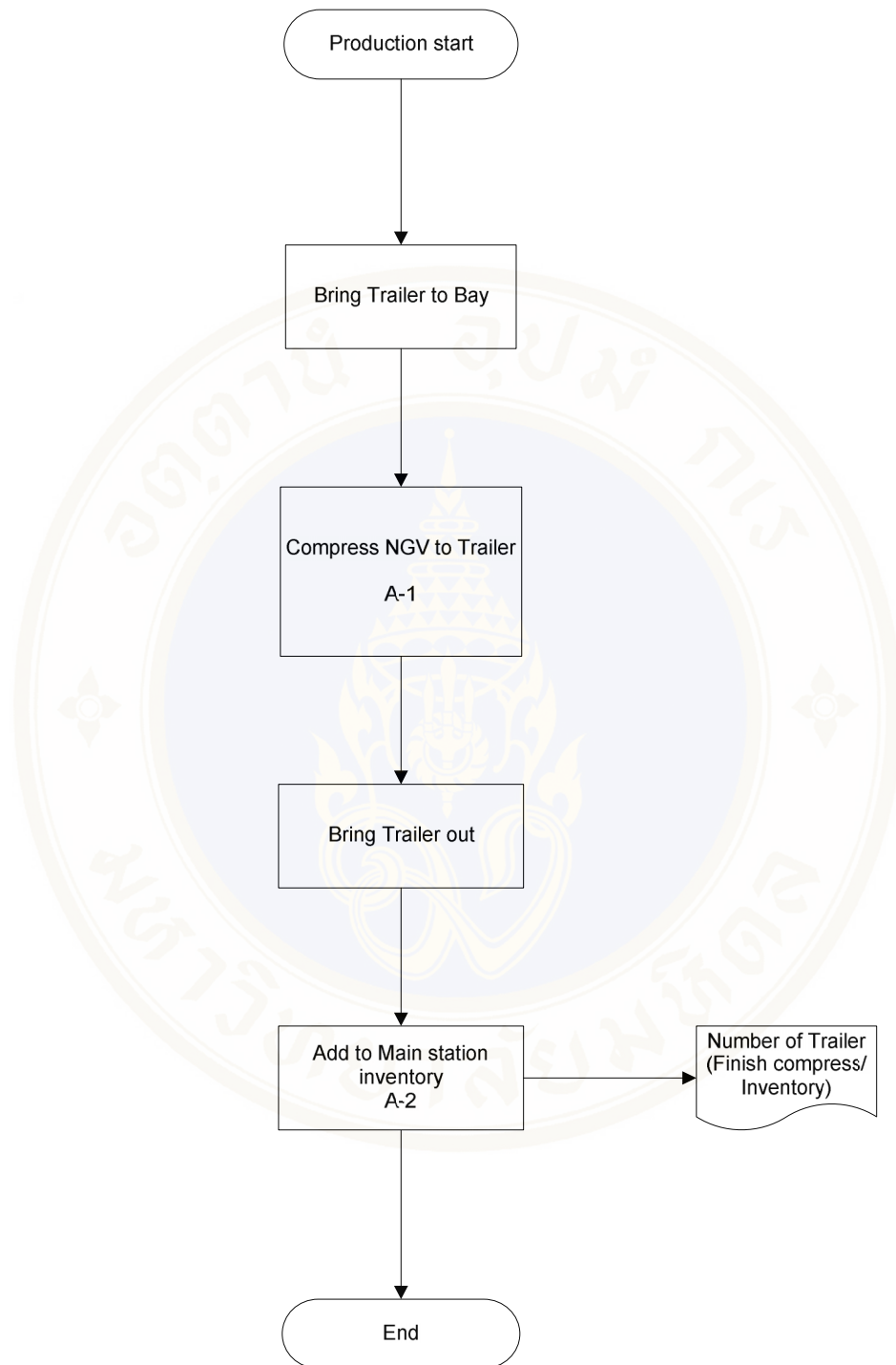


Figure 4.3 the operation of the production department of the main station

The status of trailer and delivered substation depends on the time for containing. The main station 1 will verify every 150 minutes and the main station 2 will verify every 120 minutes.

3. The transport department will bring the truck to pull the trailer as specified [C-1] to deliver at the specified substation [C-2] and to pull the empty trailer (trailer at substation) back to the main station [C-3]. As shown in figure 4.4.

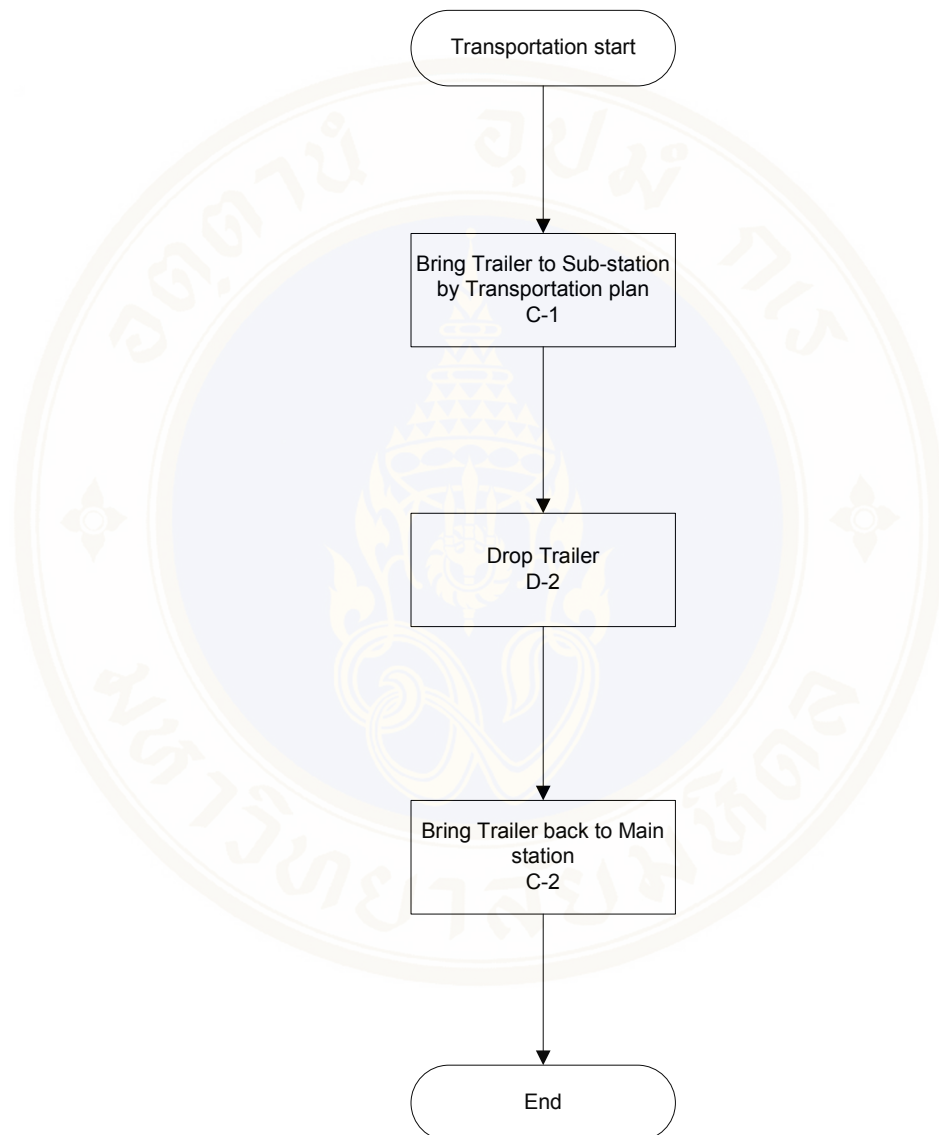


Figure 4.4 the operation of the transportation department of the main station

The work process of the substation is to update pressure level in trailer to main station by Skype system [D-1] and provide service to customers [D-3]. Then send the warning signal to the main station when the pressure in the substation trailer is at 1000 psi [D-1.1] which would stop the service to customers [D-4] and when the

pressure is 500 psi [D-1.2]. The heavy trailer [D-2] will be arrived at the station to replace the substation trailer [D-5]. It will be changed when (i) the pressure in the trailer is at 500 - 700 psi, (ii) the waiting time for the truck to replace the Trailer reaches 1 hour, and (iii) compressor at the main station has broken down.

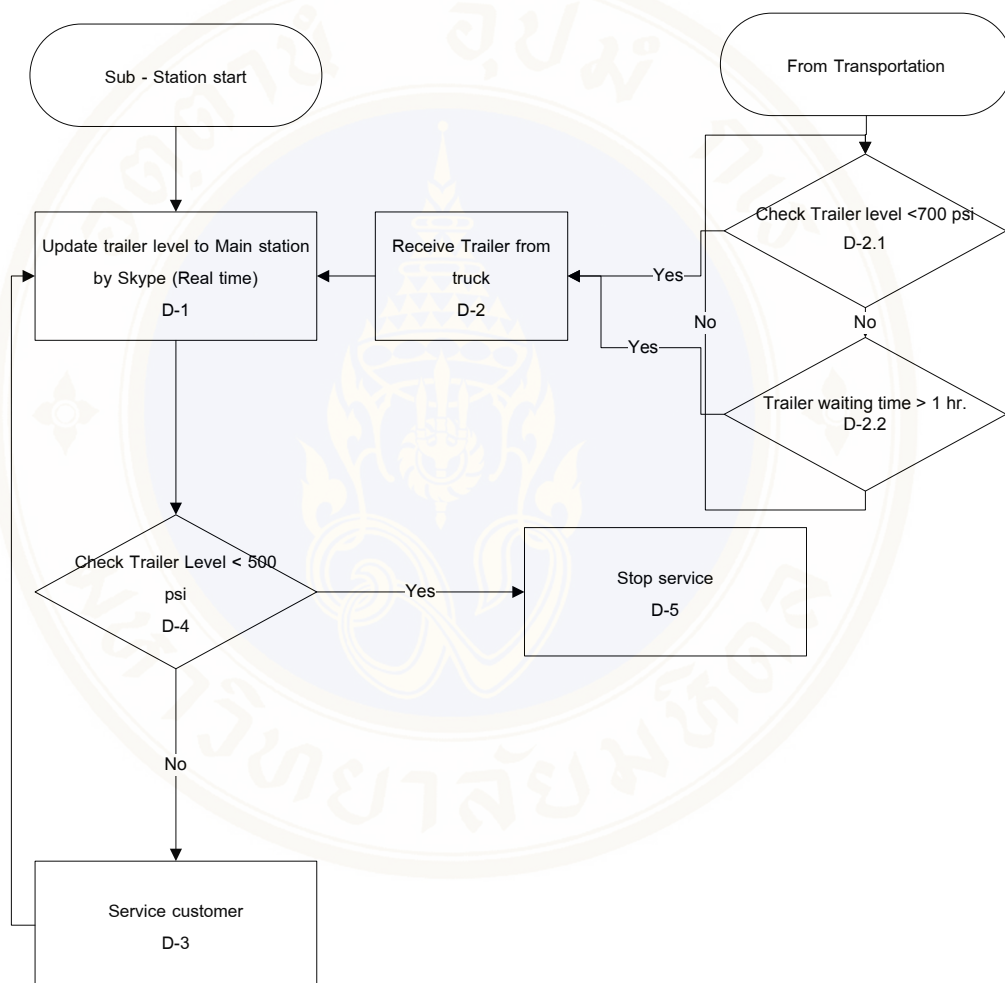


Figure 4.5 the work operation of substation

4.2 Problem description

Local Gas Company is manufacture and service operator of NGV in Thailand. The NGV is an alternative of motorists and potentially higher adoption rates. A survey of service stations found that users receive services for a long time. The

filling time is three to five minutes per car. In addition, some NGV service stations are shortage of gas and it impacts the income due to inappropriate gas transportation management NGV. There are two types of NGV transportation in Thailand.

1. Pipeline transportation systems which deliver gas only at stations located along the line. The pipeline contains only conventional stations and Mother stations (main station). It is the same process for conventional stations and Main stations but the Main station will serve two; gas filling and customer service.

2. Trailer transportation system for transport NGV to station outside the pipeline (substation), which was approximately 70% of all stations.

The scope of this work will be focused on trailer transportation system. The substations which are transported by main station 1 and main station 2 are shown in table 4.1.

Table 4.1 Substations are carried by main station 1 and main station 2

Main station1	Main station 2
A1	B1
A2	B2
A3	B3
A4	B4
A5	B5
A6	B6
A7	B7
A8	B8
A9	B9
A10	B10
A11	B11
A12	B12
A13	B13
A14	
A15	

Production department is continuous process. Its duty is to fill NGV into trailer. The gas fill rates are different between main station 1 and main station 2. It is up to size and number of compressor at main station. The gas fill rate of main station 1 is one hundred and fifty minutes per twelve trailers per eight compressors. While the gas fill rate of main station 2 had three types.

- 1) One hundred and ten minutes per three trailers per four compressors
- 2) One hundred and twenty minutes per two trailers per four compressors
- 3) Two hundred and forty minutes per four trailers per three compressors

Each substation has different capacity. Capacity of substation is shown in table 4.2

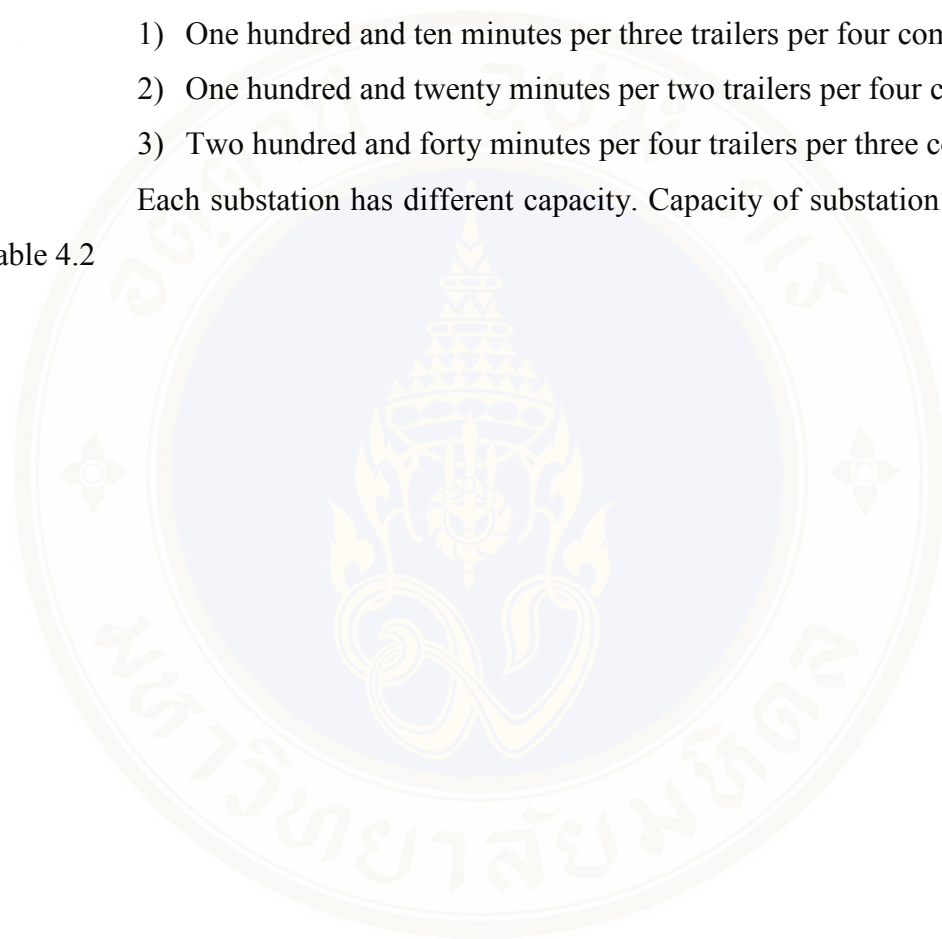


Table 4.2 Capacity of substation

Substation	Number of trailer at substation
A1	2
A2	2
A3	1
A4	2
A5	2
A6	2
A7	1
A8	2
A9	2
A10	2
A11	1
A12	2
A13	1
A14	1
A15	1
B1	1
B2	1
B3	2
B4	1
B5	1
B6	1
B7	1
B8	1
B9	1
B10	1
B11	1
B12	1
B13	2

Trailer is delivered for substations when pressure level in trailer is equal to one thousand psi. The trailer will be changed when pressure level in trailer is lower than seven hundreds psi or truck waits for an hour. The advantage of substation with two trailers is that when one trailer is empty, substation is still able to serve customers. However the substation with one trailer will have to stop to wait for heavy trailer from the main station. The delayed transportation is the factor which affects a shortage of NGV and causes loss of revenue. Substations will stop serving customers when the pressure level of trailer equal to five hundreds psi.

From the data above, the company needs to analyze problem and improve trailer transportation. The company allows fifteen minutes for delayed transportation. The company collects Number of delayed transportation at B1 equals to 104 times. In this study will improve trailer transportation by changing reorder points and number of trailers for main station. There are two parts on decision making process.

1. The new reorder point by using minimum delivery time, maximum delivery time, and average delivery time with uncertain demand.
2. Optimal number of trailers at main station by setting objective to maximum utilization of trailer. There are three constraints for these optimal numbers: Number of shortage all substations at main, on time all substations at main and Number of early at substation are less or equal the previous result. Analyzing tool is called OptQuest.

This study used key performance indicators (KPIs) as follows.

1. Utilization of trailer at main
2. Wait time for transport trailer at main
3. Number of shortage at substation
4. Number of shortage all substations at main
5. Shortage time at substation
6. Shortage time all substation at main
7. Number of early at substation
8. Number of early all substation at main
9. Wait time for change trailer at substation
10. Wait time for change trailer all substation at main

11. Number of on time at substation
12. On time all substations at main
13. Number of real late at substation
14. Real Late all substation at main
15. Order lead time at substation
16. Order lead time all substations at main
17. Late time at substation
18. Total late time all substation at main

The table below shows KPIs with definition, functions, and target

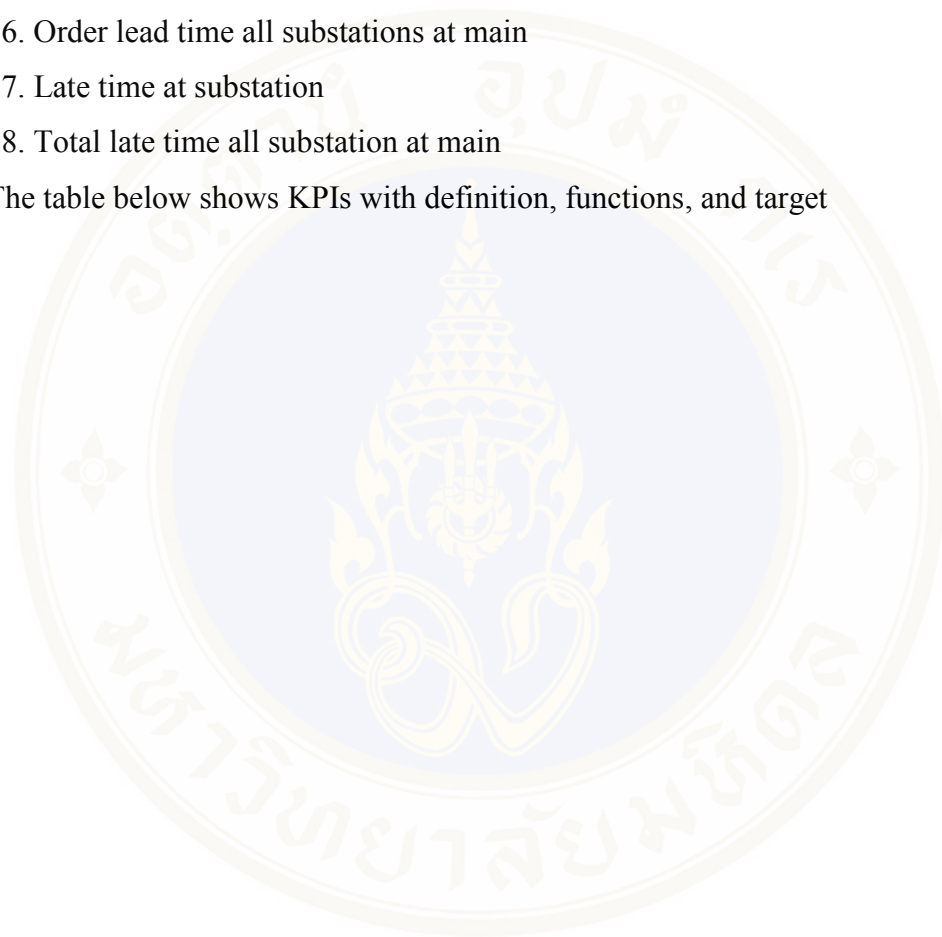


Table 4.3 KPI with function and target

No.	KPI	Function	Target	
			reorder point	optimal trailer
1	Utilization of trailer at main	$DAVG(\text{container } 1, \text{NumberBusy}) / \text{trailer cap}$		✓
2	Wait time for transport trailer at main	$TAVG(\text{Hold for pickup Queue}, \text{WaitingTime})$		✓
3	Number of shortage at $\text{subi}(i=1 \text{ to } 15)^*$	$NC(\text{Shortage time}, i=1 \text{ to } 15)^*$	✓	✓
4	Number of shortage all sub at main	$\sum NC(\text{Shortage time}, i=1 \text{ to } 15)^*$	✓	✓
5	Shortage time at $\text{subi}(i=1 \text{ to } 15)^*$	$TAVG(\text{Record shortage time}, i=1 \text{ to } 15)^*$	✓	✓
6	Shortage time all sub at main	$\sum TAVG(\text{Record shortage time}, i=1 \text{ to } 15)^*$	✓	✓
7	Number of early $\text{vi}(i=1 \text{ to } 15)^*$	$NC(\text{early}, i=1 \text{ to } 15)^*$	✓	
8	Number of early all sub at main	$\sum NC(\text{early}, i=1 \text{ to } 15)^*$	✓	
9	Wait time for change trailer at $\text{subi}(i=1 \text{ to } 15)^*$	For first trailer: $TAVG(\text{Hold for fullfill tanki Queue}, \text{WaitingTime}, i=1 \text{ to } 15)$ For second trailer: $TAVG(\text{Hold for fullfill tanki}_2 \text{ Queue}, \text{WaitingTime}, i=1 \text{ to } 15)^*$	✓	

Table 4.3 KPI with function and target (cont.)

No.	KPI	Function	Target	
			reorder point	optimal trailer
10	Wait time for change trailer all sub at main	$\sum \text{TAVG}(\text{Hold for fullfill tanki_Queue. WaitingTime}_{i=1 \text{ to } 15}) + \text{TAVG}(\text{Hold for fullfill tanki_2.Queue. WaitingTime}_{i=1 \text{ to } 15})$ *	✓	
11	Number of on time $(i=1 \text{ to } 15)$ *	$\text{NC}(\text{ontime}_{i=1 \text{ to } 15})$ *	✓	
12	On time all sub at main	$\sum \text{NC}(\text{ontime}_{i=1 \text{ to } 15})$ *	✓	
13	Number of real late $(i=1 \text{ to } 15)$ *	$\text{NC}(\text{Real late}_{i=1 \text{ to } 15})$ *	✓	✓
14	Real Late all sub at main	$\sum \text{NC}(\text{Real late}_{i=1 \text{ to } 15})$ *	✓	✓
15	Order time at sub $(i=1 \text{ to } 15)$ *	$\text{TAVG}(\text{order leadtime}_{i=1 \text{ to } 15})$ *	✓	✓
16	Order lead time all sub at main	$\sum \text{TAVG}(\text{order leadtime}_{i=1 \text{ to } 15})$ *	✓	✓
17	Late time at sub $(i=1 \text{ to } 15)$ *	$\text{TAVG}(\text{late time}_{i=1 \text{ to } 15})$ *	✓	✓
18	Total late time all sub at main	$\sum \text{TAVG}(\text{late time}_{i=1 \text{ to } 15})$ *	✓	✓

*For main station 1 $(i=1 \text{ to } 13 \text{ for main station } 2.)$

4.3 Conceptual Model

There are three types of entity in concept of model.

1. Gas for pipeline for refilling the trailer involved in production department.
2. Plan to rearrange order to transport involved in gas management department and transportation department.
3. Demand to decrease pressure level in trailer at substation

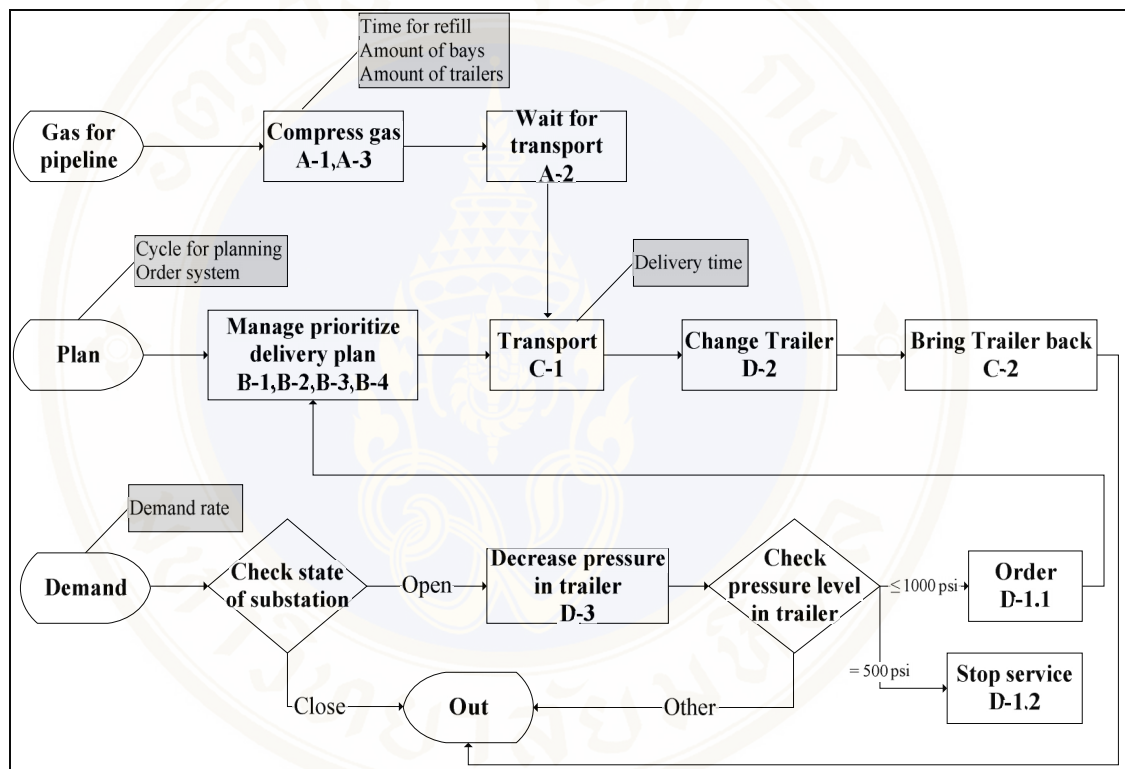


Figure4.6 concept model with input data

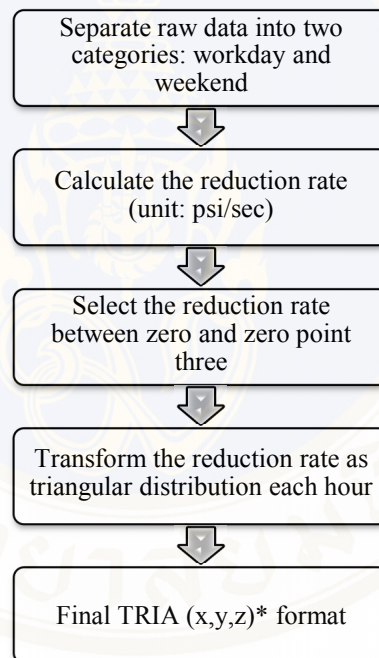
Input data has divided into four departments.

1. Production department used time and the number of bays for filling up gas and the existing number of the trailer. These data had collected by interview.
2. Gas management department used the time round in planning. Cycle for planning at the main station 1 is 150 minutes and 120 minutes at main station 2. This data had collected by interview.

3. Transportation department used delivery time from main station to substation and changing trailer rule. The delivery time had collected by raw data while changing trailer rule had collected by interview.

4. Substation department used demand rate and order system. This study used the reduction rate in each period of the day instead of demand rate. The reduction rate had collected by interview and raw data. Substations demand trailer when pressure trailer is equal to 1000 psi.

There are four steps to transform raw data of pressure level to reduction rate as following figure4.11 and the reduction rate of each substation is shown in appendix A.



*TRIA(X, Y, Z) means triangular distribution with minimum value is X, most likely value is Y, and maximum value is Z.

Figure 4.7 step of raw data of pressure level to reduction rate

4.3.1 Input Analysis

4.3.1.1 The delivery time data from the main station to each the substations

The data will be analyzed to find the format of the probability distribution by using Chi Square Test. Table 4.4 shown p-value from main station 1 to substation and Table 4.5 shown p-value from main station 2 to substation.

Table 4.4 Delivery time with p-value from main station 1 to substation

To/From	Main station 1 (minute)	p-value
A1	TRIA(21.5,25.2,47.5)	0.698
A2	TRIA(22.5,36.5,68.5)	> 0.75
A3	TRIA(17.5,29,37.5)	0.0187
A4	TRIA(9.5,11,22.5)	0.018
A5	TRIA(30.5,37.5,76.5)	0.307
A6	TRIA(17.5,54.6,96.5)	0.167
A7	TRIA(11,13,67)	0.005
A8	45	-
A9	TRIA(17,44,164)	0.005
A10	60	-
A11	TRIA(10,15.5,31)	0.0365
A12	TRIA(54.5,80.9,111)	>0.75
A13	50	-
A14	25	-
A15	TRIA(9.5,15,27.5)	>0.75

Table 4.5 Delivery time with p-value from main station 2 to substation

To/From	Main station 2 (minute)	p-value
B1	TRIA(40,51.5,108)	0.00722
B2	TRIA(17,24.5,47)	0.049
B3	TRIA(29.5,47,100)	0.062
B4	TRIA(36.5,51.5,106)	0.195
B5	TRIA(34.5,48.5,99.5)	0.458
B6	TRIA(21.5,35,84.5)	0.0322
B7	TRIA(19.5,32,57.5)	0.0256
B8	TRIA(11.5,25,45.5)	0.381

Table 4.5 Delivery time with p-value from main station 2 to substation (cont.)

To/From	Main station 2 (minute)	p-value
B9	TRIA(29.5,46,96.5)	0.00951
B10	TRIA(19.5,25.5,58.5)	>0.75
B11	TRIA(44.5,56.9,80.5)	0.0208
B12	TRIA(13.5,33.9,35)	0.0948
B13	TRIA(40,54.6,156)	>0.75

Three types of variable and attribute were used as follow table 4.6, table 4.7, table 4.8, and table 4.9

Table 4.6 Decision variable

Variable	Definition
trailer cap	Number of trailer
vary	Addition ratei
time	Time for delayed trailer

Table 4.7 Checking variable

Variable	Definition
Tank level si	Trailer has ready to work at substationi
back to main	Number of trailers are back to main station
delivery to sub station	Number of trailer are transport to substation
inventory no	Number of heavy trailers
reorder i	Order has came from substationi

Table 4.8 Variable for calculated KPI

Variable	Definition
empty timei	Time when pressure level of trailer equal to five hundred psi at substationi
full timei	Time when trailer has changed at substationi
inventory no	Number of heavy trailers

Table 4.8 Variable for calculated KPI (cont.)

Variable	Definition
order time _i	Time when order of substation _i
var_shortage time _i	Time when substation _i has shortage gas

Table 4.9 Attribute

Attribute	Definition
Att_late ₁	Delayed trailer at substation _i
for full ₁	Time when trailer arrived to substation _i
re	Order of substation
Att_rei	Order of tank _i at substation

4.3.2 Model description

The model will be divided into 4 parts.

1. Gas filling part which gas is filled into the trailer. This is the operation of main service stations. The operation will start when the gas is attained and held until the trailer is free to contain. After that, the filling will be performed by compressor and waiting order to be sent to the substations. The figure 4.9 shows the model of gas filling part.

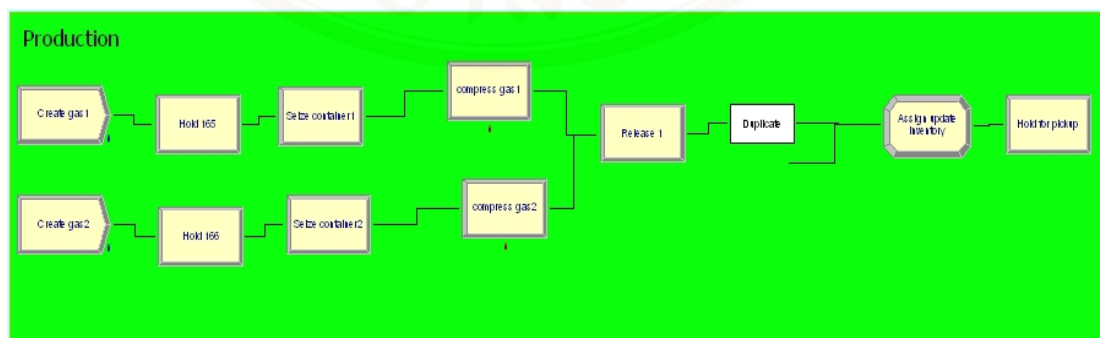


Figure 4.8 Model from section 1

From figure 4.8, starting from generating gas and then it is held until the trailer is light enough to fill up, compressor is empty and then seize the resource with the name container 1. After that the gas will be filled up using fixed time by the

resource with the name compressor. Once the gas has been filled into the trailer, the number of filled trailer will be noted and the trailers are ready to release to any substations with the order.

2. Gas management, trailers will be sent in order. It is a part of the main station operation by starting from the order and choose the awaiting one then bring the trailer which has been filled up to the part of the ordering. In the case, the Order in the part is not in the ordering round. However it waits until the order amount in the ordering round is empty and the filled trailer will be sent along. The figure 4.9 shows the model of gas management.

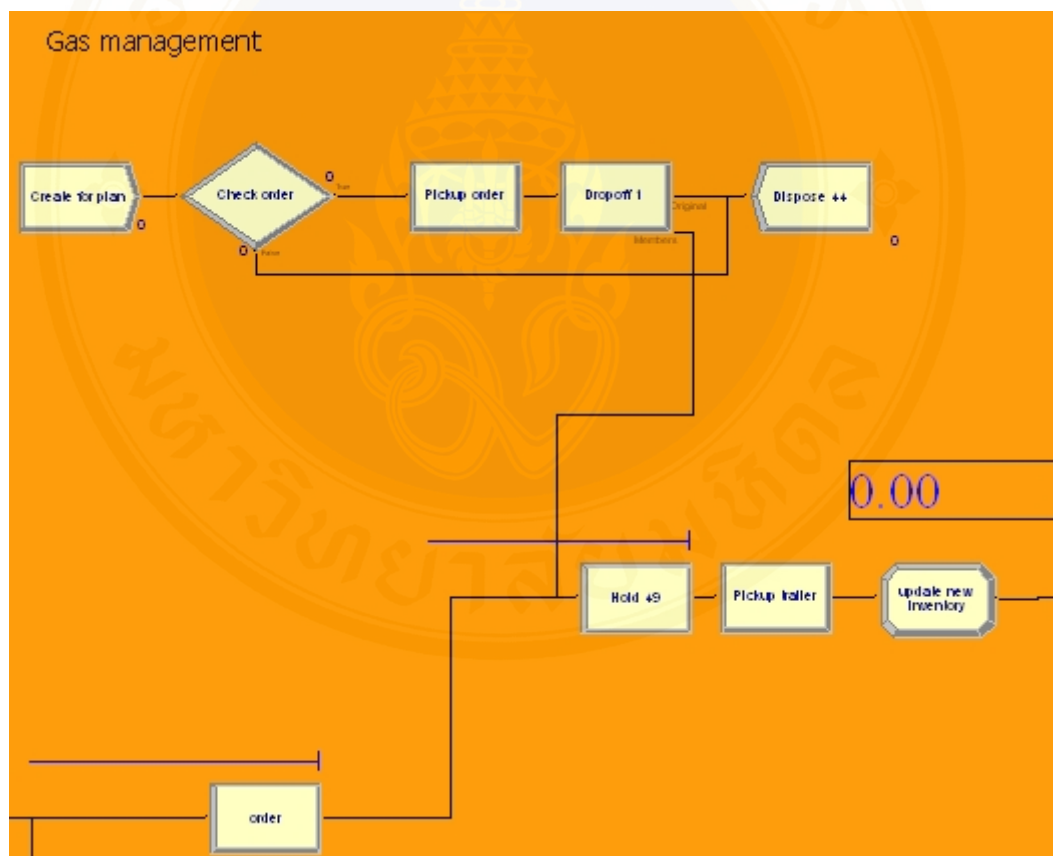


Figure 4.9 Model from section 2

From figure 4.9, it is started by creating the ordering round of the delivery. It is done by checking the availability. If there is a waiting order, the order will be picked but if there is no waiting order it will be eliminated. After that if there is heavy

trailer to be used in the delivery, it is the priority to select the heavy trailer to alternate with the former one. Then the delivery process is initiated.

3. Gas delivery part, the trailers will be sent to the substation and will start the work upon the arrival. It will separate the substations which are delivered according to the order. After that it will be delivered to the substations and when the trailer has been changed, it will return to the main stations. The figure 4.10 shows the model of gas delivery part.

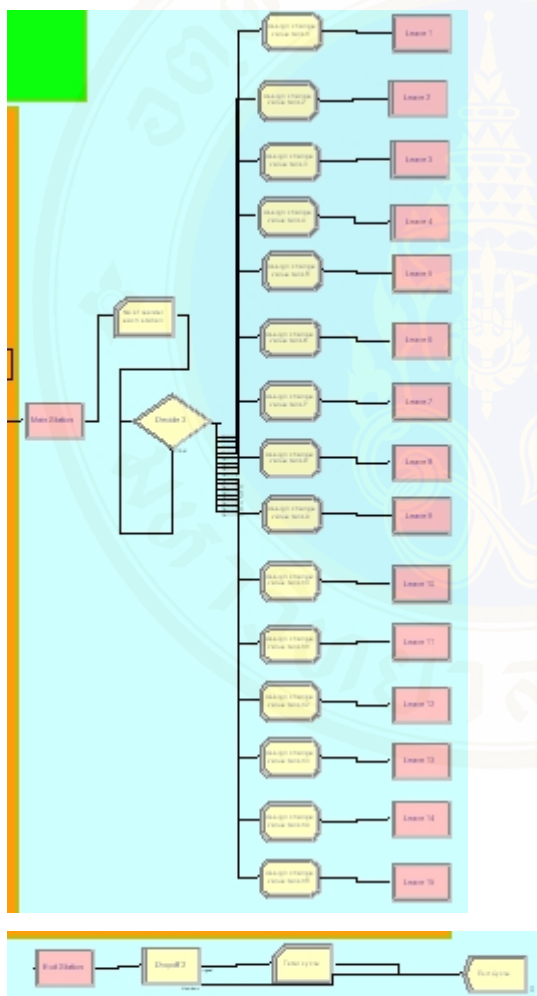


Figure 4.10 Model from section 3

From figure 4.10, it starts from sending the trailer to the substations same as the gas management and receive the light trailer (trailer with the pressure less than 700 psi to less than or at 500 psi) from the substation to the main station.

4. As for the substations, the work starts when the gas demand is identified and the trailer pressure is reduced at the substations according to the gas demand. When the pressure in the trailer reaches 1000 psi, the order will be sent to the main stations and when the pressure in the trailer is 500 psi, the service will stop (in the case there is only one trailer at the service station). When the delivered trailer has come to the substations it will be checked for its punctuality in order to change the trailer at the substations. After that the trailer will be alternated. The substation can be divided into 2 types.

4.1. Substation with 2 trailers

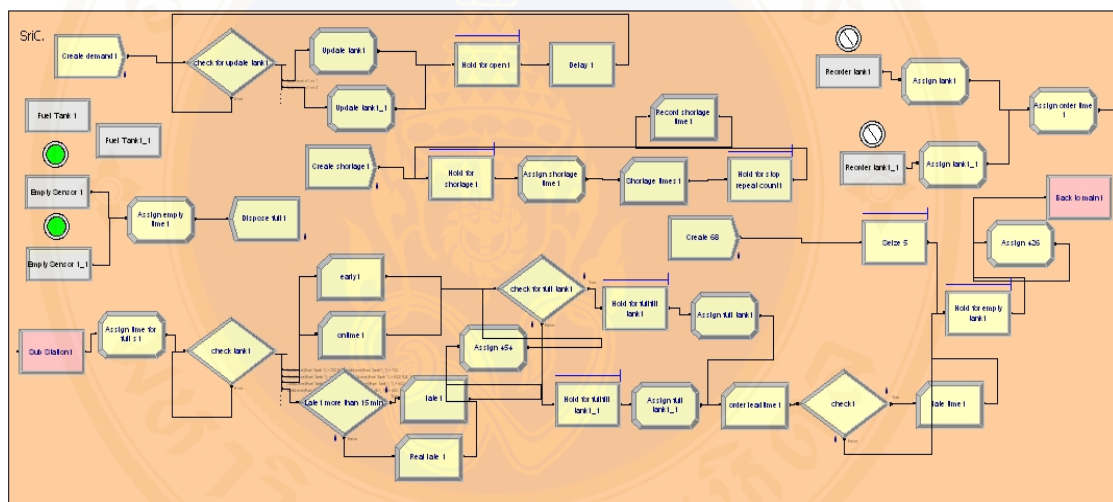


Figure 4.11 Model from section 4 type 1

From figure 4.11, it starts from the requirement of gas, then select the trailer to adjust the pressure. After that the pressure in the trailer is reduced by using assign. Pause until the substations are able to provide the service, then relay the time (1 sec.) The trailer will be once again selected. When the pressure in the trailer is at 1000 psi, the order will be made and specify which substation is designated, when to start the order and which trailer will be used. The delivery time will be calculated for its punctuality for changing the trailer. When the trailer is changed, it will be redirected to the original trailer. Thus there are two trailers to provide the service to customers. The service is stopped when the pressure of both trailers is less than or at 500 psi.

4.2 Substation with one trailer

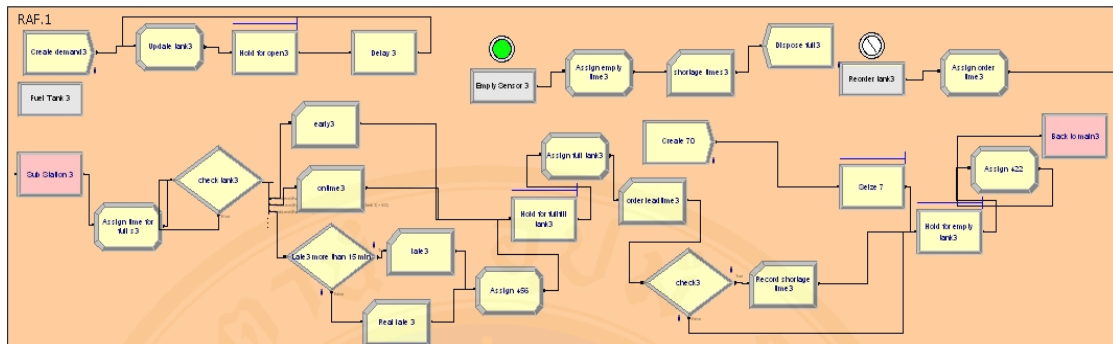


Figure 4.12 Model from section 4 type 2

From figure 4.12, it starts from the requirement of gas, and then the assign will be used for changing the pressure in the trailer. Wait until the substations are able to provide the service, then relay the time (1 sec.). After that, adjust the pressure in the trailer again. When the pressure in the trailer is at 1000 psi, the order will be made and specified which substation is at the best convenience to deliver as well as the time for the order and change of trailers. Once the delivering trailer has reached the substations, it will be checked for its punctuality. The service is stopped when the pressure of both trailers is less than or at 500 psi.

4.4 Verify Model

The verification of the program will be considered from the its operation whether it is according to the specified plan or not and crossed check verify condition by following Table4.10.

Table4.10 Verify condition

Verify Condition
$NQ(\text{Seize container.Queue}) == 0$
$NQ(\text{compress.Queue}) == 0$
$\text{Record shortage time} == \text{Hold for open.Queue.WaitingTime}$
$\text{NumberOut.Hold for open} == \text{NumberOut.Record shortage time} == \text{Shortage times}$

4.5 The analysis of the warm-up period

Warm-up period in this study is calculated from graph of inventory number. The figure below shows warm-up period of main station 1.

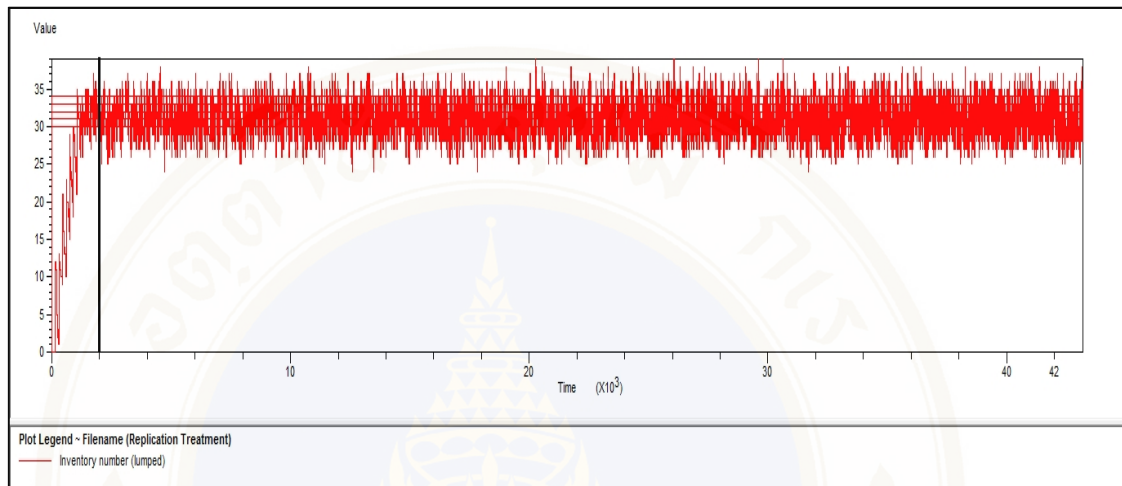


Figure 4.13 Graph of inventory number of main station 1 at any time

From figure 4.13, warm-up period was calculated by two thousand divided by one thousand four hundred and forty. Then, warm-up period of main station 1 is equal two days. The figure below shows warm-up period of main station 2.

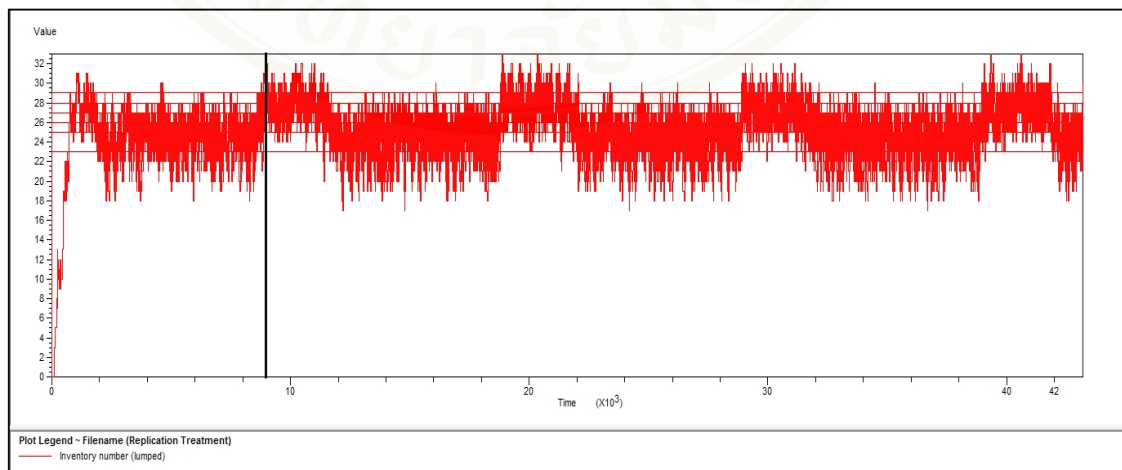


Figure 4.14 Graph of inventory number of main station 2 at any time

From figure 4.14, warm-up period was calculated by nine thousand divided by one thousand four hundred and forty. Then, warm-up period of main station 2 is equal to seven days.

4.6 Validate Model

The model has been validated by comparison between the actual numbers of delayed transportation at B1 and from the model. It is 104 times for the actual data while it is 103.82 times for the model. The model stand deviation was equal to 3.057. The actual and the model delayed transportation times are similar at α equal to 0.05.

4.7 The analysis of the number of replications

From thirty replications, expected Half Width was less than test replication Half Width because the number of replications is not enough. So the new number of replications is calculated and it is one hundred and eighty five. The result of 185 replications of main station 1 is shown in appendix B.

CHAPTER V

RESULT

This chapter will discuss on the effects of decision variables which consist of reorder point and number of trailers. This chapter is organized as follow. The first part will be focused on an adjustment of the reorder point for decreasing the number of gas shortage times and increasing the number of on time delivery. The second part will be discussed on the sensitivity analysis of new reorder points. Finally, the number of trailers at main stations will be discussed as well.

5.1 Main station 1

5.1.1 The current situation (AS-IS)

The table 5.1 shows KPIs name, their values and Half-width. It shows that the utilization of trailer is 52.08 percent. The average waiting time of trailer to transport a substation is 589 minutes per month or 19 minutes / day. The average order lead time of all substations is 750.52 minutes or 50 minutes / stations. The result of delivery equals to 2277 times per month. The number of early deliveries is 1616 times by the average early time delivery of all substations is 274 minutes or 18.27 minutes / station. The number of on time deliveries is 659 times, and the number of delayed deliveries is two times by the average late time of all substations was 20.4 minutes or 1.36 minutes / station. The result shows that the number of early deliveries is 70 percent of all delivery. The result of the simulation at substations is shown in figure 5.1.

Table 5.1 The result of current situation at main station 1 with KPIs

KPI	Name in Model	Value	Half-width
Utilization of trailer at main	Utilization of trailer at main1	0.5208	0
Wait time for transport trailer at main	Wait time for transport trailer at main1	645.02	0.1
Number of shortage all sub at main	Number of shortage all sub at main1	0	0
Shortage time all sub at main	Shortage time all sub at main1	0	0
Number of early all sub at main	Number of early all sub at main1	1559.25	1.33
Wait time for change trailer all sub at main	Wait time for change trailer all sub at main1	273.96	2.12
On time all sub at main	On time all sub at main1	475.627	1.387
Real Late all sub at main	Real late all sub at main1	184.52	0.65
Order lead time all sub at main	Order lead time all sub at main1	750.52	1.46
Total late time all sub at main	Total late time all sub at main1	11.304	0.15

According to Figure 5.1, the number of on time deliveries at A2, A8, A10, and A13 are greater than the number of early deliveries. There are many early delivery times at other substations especially A3 A4 A5 A6 A7 A11 A12 A14 and A15.

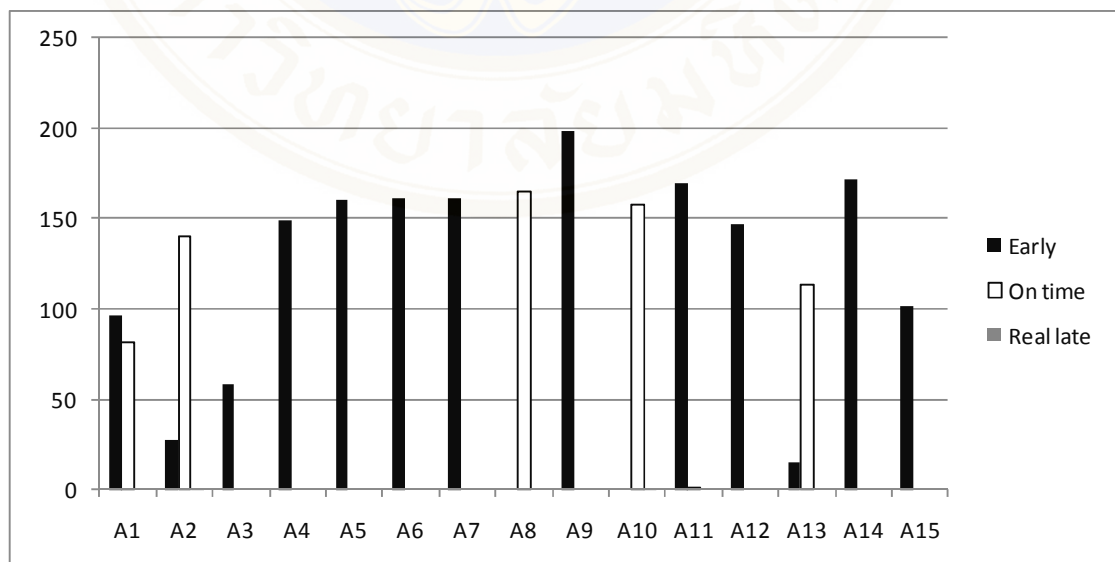


Figure 5.1 The result for each substation at main station 1

5.1.2 Adjust reorder point

According to AS-IS, the delivery status is almost early delivery. In this scenario, substation reorder points are modified to improve NGV transportation system. New substation reorder points are shown in the table 5.2.

Table 5.2 The new reorder point for each substation of main station1

Substation	New reorder point (psi)		
	Min (TO-BE1)	Average (TO-BE2)	Max (TO-BE3)
A1	901	1,089	1,372
A2	840	1,143	1,536
A3	550	572	606
A4	585	621	702
A5	870	1,079	1,429
A6	865	1,672	2,512
A7	591	646	752
A8	1,048	1,048	1,048
A9	874	1,600	3,000
A10	1,150	1,150	1,150
A11	611	689	844
A12	1,108	1,414	1,738
A13	967	967	967
A14	775	775	775
A15	565	618	820

The results of adjusting reorder point each substation by comparing to AS-IS are shown in the table 5.3

Table 5.3 The result of adjusting reorder point each substation with KPIs at main station 1

KPI	Name in Model	AS-IS	TO- BE1	TO- BE2	TO- BE3
		Value	Value	Value	Value
Utilization of trailer at main	Utilization of trailer at main1	0.5208	0.5096	0.5220	0.5433
Wait time for transport trailer at main	Wait time for transport trailer at main1	588.64	626.84	591.95	555.17
Number of shortage all sub at main	Number of shortage all sub at main1	0	413.27	223.2	54.5333
Shortage time all sub at main	Shortage time all sub at main1	0	58.4738	19.1805	17.0420
Number of early all sub at main	Number of early all sub at main1	1615.70	834.07	1222.17	1296.10
Wait time for change trailer all sub at main	Wait time for change trailer all sub at main1	273.96	273.96	310.73	915.50
On time all sub at main	On time all sub at main1	658.73	1297.90	852.93	829.33
Real Late all sub at main	Real Late all sub at main1	1.8	58.933	32.301	11.101
Order lead time all sub at main	Order lead time all sub at main1	750.52	584.31	698.76	698.76
Total late time all sub at main	Total late time all sub at main1	20.4076	69.9387	34.0055	30.9168

Due to the table 5.3, the number of on time deliveries and the number of gas shortage times are increased because of reorder point adjustment. The average order lead time of all substations is lower than AS-IS since the adjusting reorder points decrease the number of early deliveries. The result of each substation is shown in the figure 5.2, 5.3, 5.4, and 5.5.

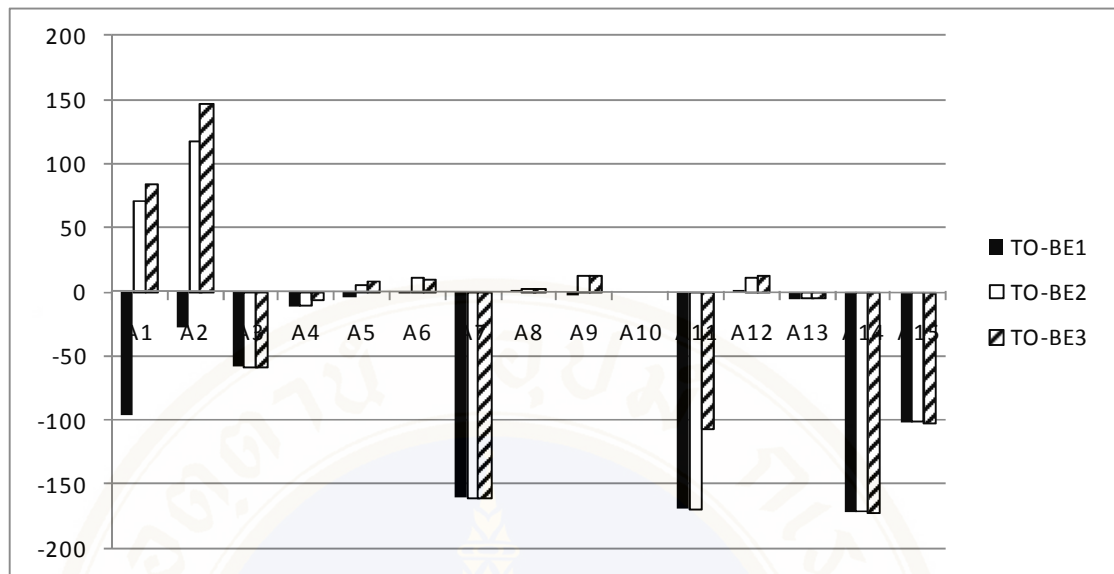


Figure 5.2 Comparison the number of early deliveries of TO-BE with AS-IS at main station 1

Due to the figure 5.2, the number of early deliveries at A1, A2, A5, A6, and A9 of TO-BE 1 decrease while TO-BE 2 and TO-BE 3 increase. The number of early deliveries at A3, A4, A6, A7, A11, A13, A14, and A15 decrease for all scenarios. The number of early deliveries at A8 and A12 increase for all scenarios.

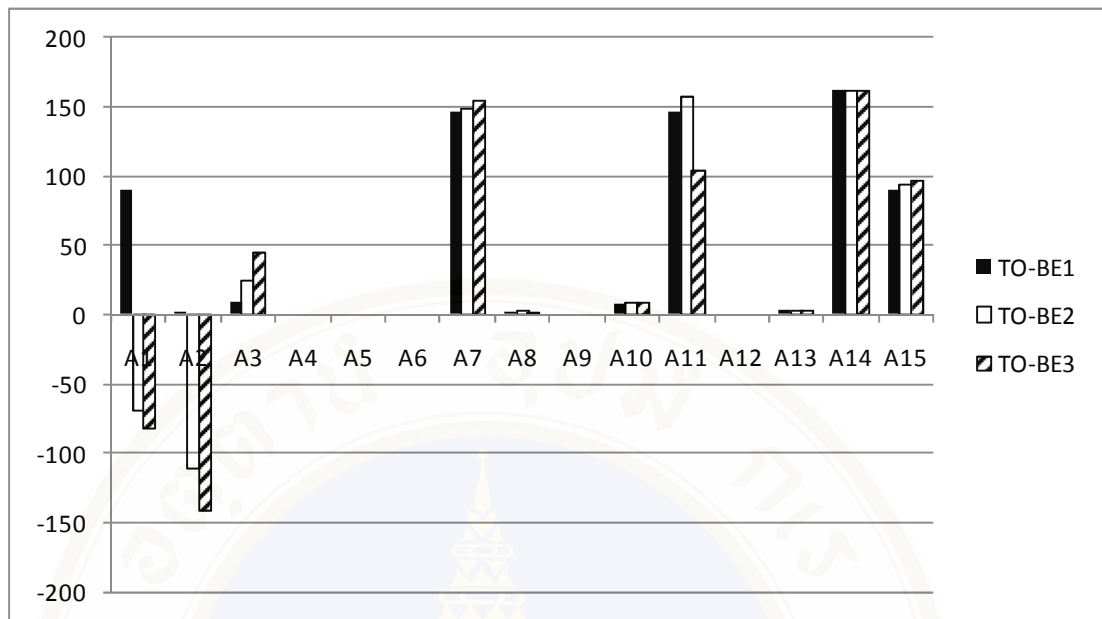


Figure 5.3 Comparison the number of on time deliveries of TO-BE with AS-IS at main station 1

According to the figure 5.3, the number of on time deliveries at A1 and A2 of TO-BE 1 increase but TO-BE 2 and TO-BE 3 are the opposite. The number of on time deliveries at A3, A7, A8, A10, A11, A13, A14, and A15 increase for all scenarios.

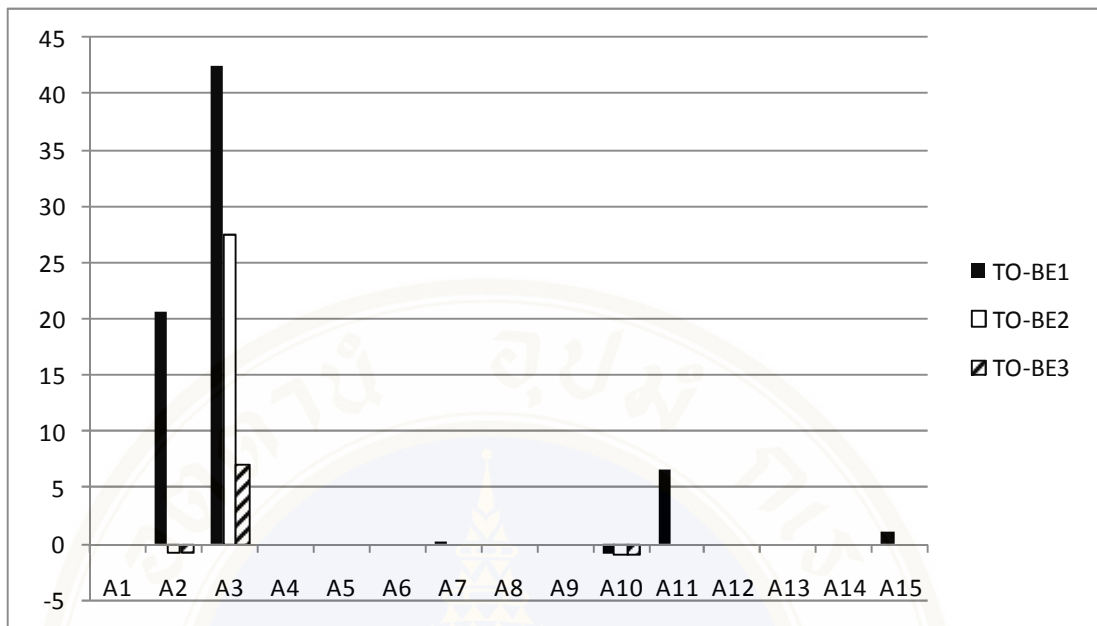


Figure 5.4 Comparison the number of delayed deliveries of TO-BE with AS-IS at main station 1

Due to the Figure 5.4, the number of delayed deliveries at A3 increases for all scenarios. The number of delayed deliveries at A7, A11, and A15 of TO-BE 1 are also increase. And the number of delayed deliveries at A2 of TO-BE 1 increases while TO-BE 2 and TO-BE 3 are the opposite.

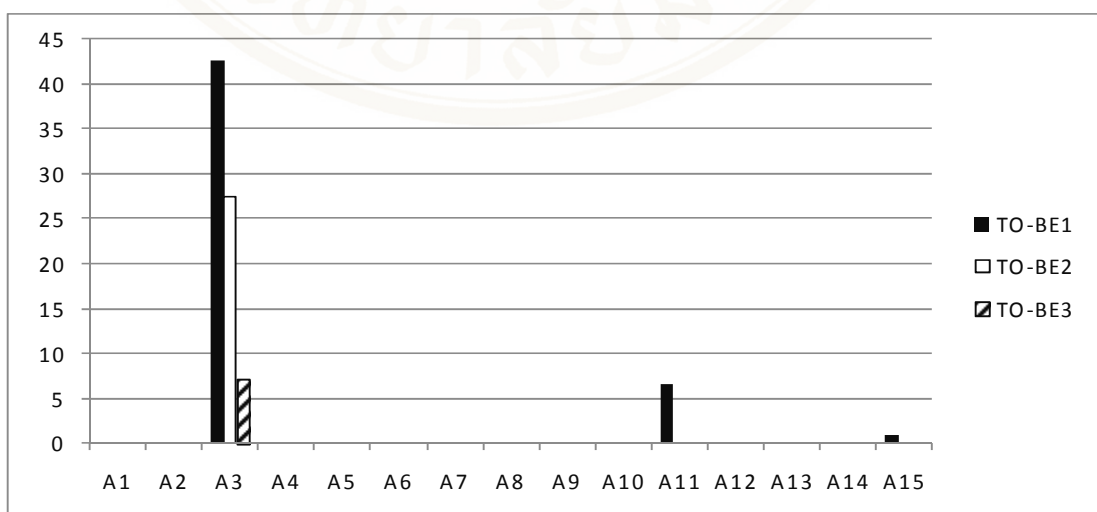


Figure 5.5 Comparison the number of gas shortage times of TO-BE with AS-IS at main station 1

According to the figure 5.5, the number of gas shortage times at A11 and A15 of TO-BE 1 is increased. The number of gas shortage times at A3 is as well increased for all scenarios.

The result from this scenario shows that adjusting reorder points increase the number of on time deliveries and the number of delayed deliveries especially A3, A11 and A15 is increased. The most important issue of natural gas transportation is to decrease the number of gas shortage times at substations. Therefore, the next scenario will consider the number of gas shortage times which should be zero. The number of on time deliveries should be increased. And the number of delayed deliveries should be decreased as well as the number of early deliver. The substations' new reorder points are shown in Table 5.4.

Table 5.4 The new reorder point for each substations

Substations	New reorder point (TO-BE4)
A1	Minimum reorder point
A2	Current reorder point
A3	Current reorder point
A4	Minimum reorder point
A5	Minimum reorder point
A6	Minimum reorder point
A7	Maximum reorder point
A8	Average reorder point
A9	Minimum reorder point
A10	Average reorder point
A11	Average reorder point
A12	Current reorder point
A13	Current reorder point
A14	Average reorder point
A15	Maximum reorder point

The result of the substations' new reorder points by comparing with AS-IS are shown in table 5.5.

Table 5.5 The result of the new reorder point for each substation with KPIs at main station 1

KPI	Name used in Model	AS-IS	TO-BE4
		Value	Value
Utilization of trailer at main	Utilization of trailer at main1	0.5208	0.5127
Waiting time for transport trailer at main	Wait time for transport trailer at main1	588.64	614.05
Number of shortage all sub at main	Number of shortage all sub at main1	0	0
Shortage time all sub at main	Shortage time all sub at main1	0	0
Number of early all sub at main	Number of early all sub at main1	1615.70	942.60
Waiting time for change trailer all sub at main	Wait time for change trailer all sub at main1	273.96	138.83
On time all sub at main	On time all sub at main1	658.73	1276.93
Real Late all sub at main	Real Late all sub at main1	1.8	1.8
Order lead time all sub at main	Order lead time all sub at main1	750.52	649.77
Total late time all sub at main	Total late time all sub at main1	20.4076	19.2282

From the Table 5.5, TO-BE 4 effects increasing of the number of on time deliveries by 93.84 percent and 41.66 percent for early delivery. The average early time delivery of all substations is 49.32 percent decreased while the average order lead time all substations decrease to 13.42 percent.

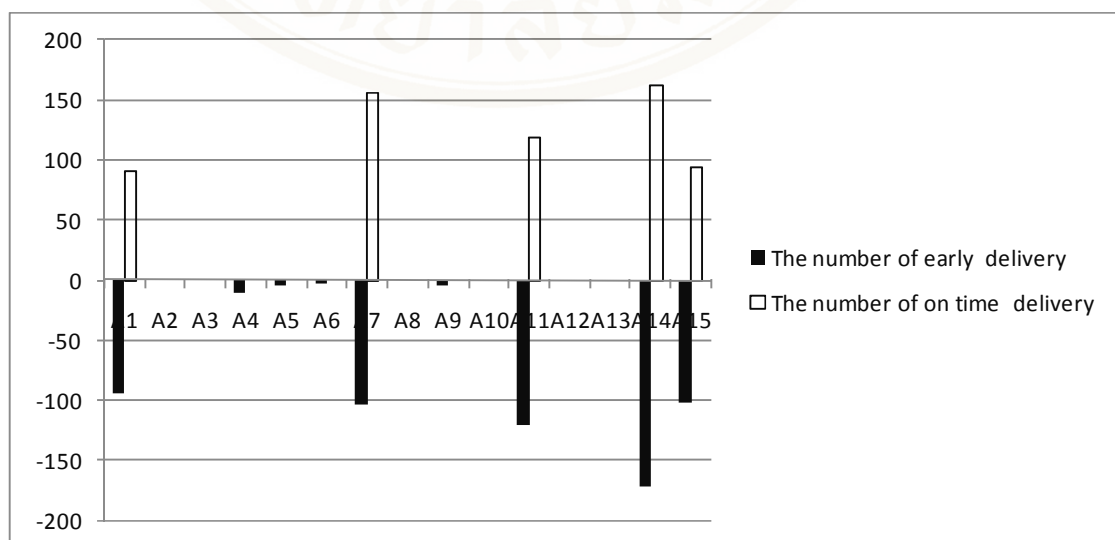


Figure 5.6 Comparison the number of early deliveries and the number of on time deliveries of TO-BE4 with AS-IS at main station 1

However, trailer utilizations are in poor condition because there are idle trailers. In the next scenario, the number of trailer will be adjusted.

5.1.3 Adjust number of trailer

In this scenario, the number of trailer will be adjusted using Optquest program. The objective function is to maximize utilizations of trailer. The main constraint is the number of gas shortage times that must be remained the same. The number of trailers of AS-IS in main station 1 is shown in the table 5.6. The number of trailers of TO-BE4 in main station 1 is shown in the table 5.7.

Table 5.6 The number of trailers of AS-IS in main station 1

KPI	Name in model	number of trailer			
		70		48	
		Value	Half-Width	Value	Half-Width
Utilization of trailer at main	Utilization of trailer at main1	0.5127	0	0.7597	0
Wait time for transport trailer at main	Wait time for transport trailer at main1	614.05	0.2	5.725	0.09
Number of shortage all sub at main	Number of shortage all sub at main1	0	0	0	0
Shortage time all sub at main	Shortage time all sub at main1	0	0	0	0
Real Late all sub at main	Real Late all sub at main1	1.8	0.4	2	0.42
Order lead time all sub at main	Order leadtime all sub at main1	649.77	2.65	743.64	3.38
Total late time all sub at main	Total late time all sub at main1	19.2282	3.92	24.0632	3.47

According to the table 5.6, utilization of trailer is raised by 75.97 percent. The average waiting time for transportation is decreased by 99.07 percent but the 48 trailers are suitable for the current situation.

Table 5.7 The number of trailers of TO-BE4 in main station 1

KPI	Name in model	number of trailer			
		70		44	
		Value	Half-Width	Value	Half-Width
Utilization of trailer at main	Utilization of trailer at main1	0.5127	0	0.8156	0
Wait time for transport trailer at main	Wait time for transport trailer at main1	614.05	0.2	109.04	0.23
Number of shortage all sub at main	Number of shortage all sub at main1	0	0	0	0
Shortage time all sub at main	Shortage time all sub at main1	0	0	0	0
Real Late all sub at main	Real Late all sub at main1	1.8	0.4	1.8	0.43
Order lead time all sub at main	Order lead time all sub at main1	649.77	2.65	649.77	2.65
Total late time all sub at main	Total late time all sub at main1	19.2282	3.92	25.19	3.74

According to the table 5.7, trailer utilization is increased by 81.56 percent. The average waiting time for transportation is decreased by 82.24 percent but 44 trailers are suitable for the current situation.

The next scenario will modify demand and delivery time for sensibility analysis of reorder point and the number of trailers.

5.1.4 Vary gas demand and delivery time

This scenario will modify demand that changes in range by 10-30 percent because the data volume of NGV is moving up to the maximum amount of 30 percent per month. And this scenario will modify the delivery time in range 10-50 percent. The results of modified AS-IS demands and delivery time are shown in figure 5.7. The results of modified TO-BE4 demands and delivery time are shown in figure 5.8.

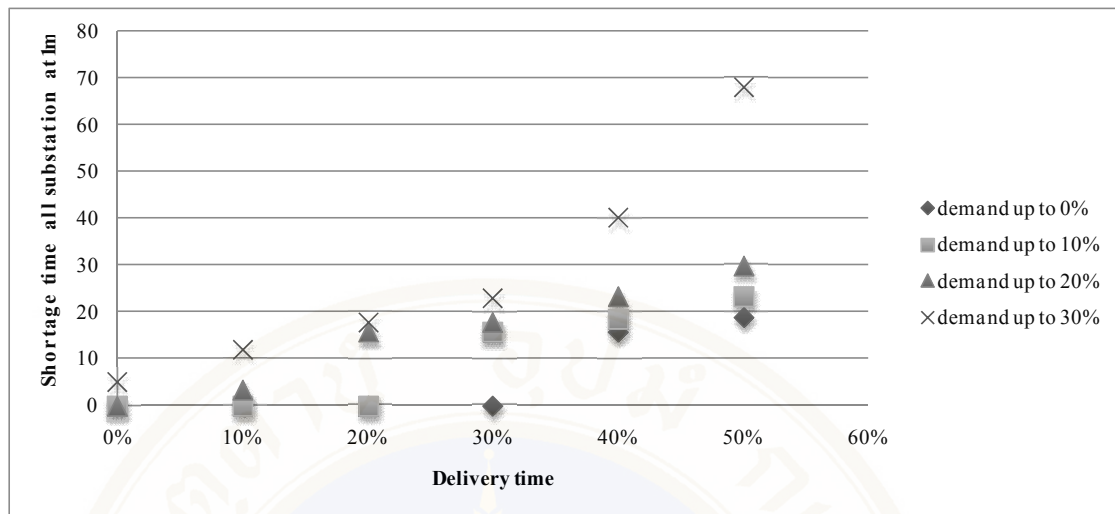


Figure 5.7 The results of modified AS-IS demands and delivery time

From figure 5.7, the increased demand of 30% is acceptable for the reorder point at 1000 psi and delivery time up to 50%. The accepted criterion is the shortage time for all substations at main1 which shall not exceed 225 minutes or 15 minutes / station. Substations with one trailer must have the number of gas shortage times, especially A13.

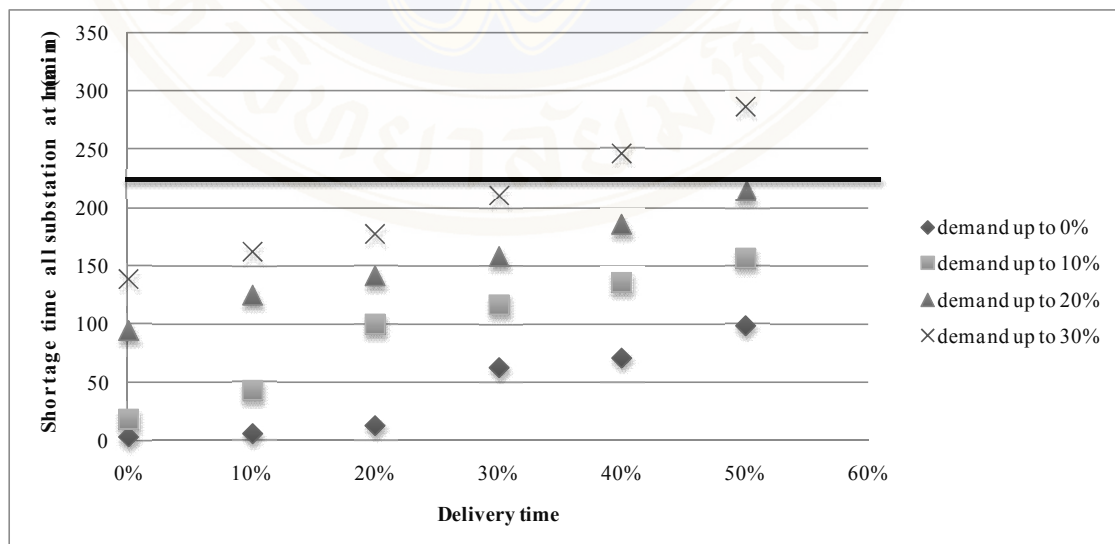


Figure 5.8 The results of modified TO-BE4 demands and delivery time

From figure 5.8, the black line represents the shortage time of all substations at main1 is 225 minutes. The reorder point from TO-BE4 is not acceptable

when the demand up to 30% and delivery time up to 40%. A7, A11, A13, A14 and A15 contain the number of gas shortage times. The suggestive solution is to change reorder point to 1000 psi or recalculated reorder point.

5.2 Main station 2

5.2.1 The current situation (AS-IS)

The table 5.8 shows KPIs name, their values and Half-width. It shows that the utilization of trailer is 49.33 percent. The average waiting time of trailer to transport to a substation is 678 minutes per month or 23 minutes / day. The number of gas shortage times of all substations is 383 times per month or 13 times / day. The average order lead time of all substations is 941.81 minutes or 73 minutes / stations. The result of delivery is 1531 times per month. The number of early deliveries is 691 times by the average early time delivery of all substations is 782 minutes or 60.15 minutes / station. The number of on time delivery is 641 times, and the number of delay delivery is 199 times by the average late time of all substations is 209.07 minutes or 16.08 minutes / station. The result shows that the number of early deliveries is similar to the number of on time deliveries. However the number of delay deliveries is 13 percent of all delivery. The results of the simulation at substations are shown in figure 5.9.

Table 5.8 The result of current situation at main station 2 with KPIs

KPI	Name in Model	Value	Half-width
Utilization of trailer at main	Utilization of trailer at main1	0.4933	0
Wait time for transport trailer at main	Wait time for transport trailer at main1	677.23	4.19
Number of shortage all sub at main	Number of shortage all sub at main1	382.20	18.06
Shortage time all sub at main	Shortage time all sub at main1	245.89	17.58
Number of early all sub at main	Number of early all sub at main1	690.20	3.77
Wait time for change trailer all sub at main	Wait time for change trailer all sub at main1	781.19	93.39

Table 5.8 The result of current situation at main station 2 with KPIs (cont.)

KPI	Name in Model	Value	Half-width
On time all sub at main	On time all sub at main1	640.80	17.23
Real Delay all sub at main	Real delay all sub at main1	198.60	14.96
Order lead time all sub at main	Order lead time all sub at main1	941.81	51.65
Total delay time all sub at main	Total delay time all sub at main1	209.07	14.93

According to figure 5.9, the number of on time deliveries at B11 is greater than one of B3, B8, B12, and B13 which are only the number of early deliveries. The next scenario will adjust reorder point each substation for decreasing the number of gas shortage times.

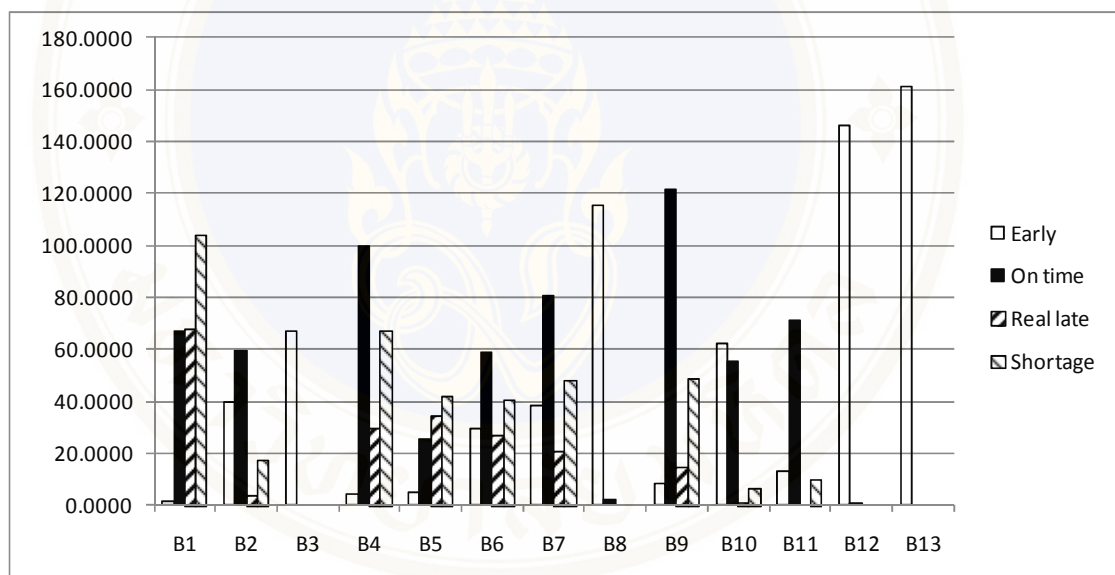


Figure 5.9 The result for each substation at main station 2

5.2.2 Adjust reorder point

According to AS-IS, there is the number of gas shortage times. In this scenario, substation reorder points are modified to reduce the number of gas shortage times. New substation reorder points are shown in the table 5.9.

Table 5.9 The new reorder point for each substation of main station 2

Substation	New reorder point (psi)		
	Min (TO-BE1)	Average (TO-BE2)	Max (TO-BE3)
1	831	1043	1565
2	590	683	1028
3	548	597	693
4	734	1031	1171
5	563	628	952
6	604	839	1213
7	608	912	1289
8	556	678	716
9	726	1136	1235
10	599	777	931
11	675	786	814
12	593	737	738
13	828	1526	1763

The results of adjusting reorder point each substation by comparing with AS-IS are shown in the table 5.10.

Table 5.10 The result of adjusting reorder point each substation with KPIs at main station 2

KPI	Name in Model	AS-IS	TO- BE1	TO- BE2	TO- BE3
		Value	Value	Value	Value
Utilization of trailer at main	Utilization of trailer at main2	0.4933	0.4557	0.4719	0.4926
Wait time for transport trailer at main	Wait time for transport trailer at main2	677.23	831.54	746.46	679.10
Number of shortage all sub at main	Number of shortage all sub at main2	382.20	1145.47	675.23	260.80
Shortage time all sub at main	Shortage time all sub at main2	245.89	463.78	333.20	194.41

Table 5.10 The result of adjusting reorder point each substation with KPIs at main station 2 (cont.)

KPI	Name in Model	AS-IS	TO- BE1	TO- BE2	TO- BE3
		Value	Value	Value	Value
Number of early all sub at main	Number of early all sub at main2	690.20	222.90	321.40	807.10
Wait time for change trailer all sub at main	Wait time for change trailer all sub at main2	781.19	18.43	265.97	1634.10
On time all sub at main	On time all sub at main2	640.80	178.10	802.07	663.97
Real Delay all sub at main	Real Delay all sub at main2	198.60	922.77	356.20	88.93
Order lead time all sub at main	Order lead time all sub at main2	941.81	799.39	826.48	981.89
Total delay time all sub at main	Total delay time all sub at main1	209.07	407.14	288.73	157.12

From table 5.10, the number of gas shortage times is decreased by TO-BE 3 but the early delivery increase. TO-BE 1 and TO-BE 2 lessen the average order lead time of all substations because the adjusting reorder point decreases the number of early deliveries but increases the number of gas shortage times. The result of each substation is shown in Figure 5.10, 5.11, 5.12, and 5.13.

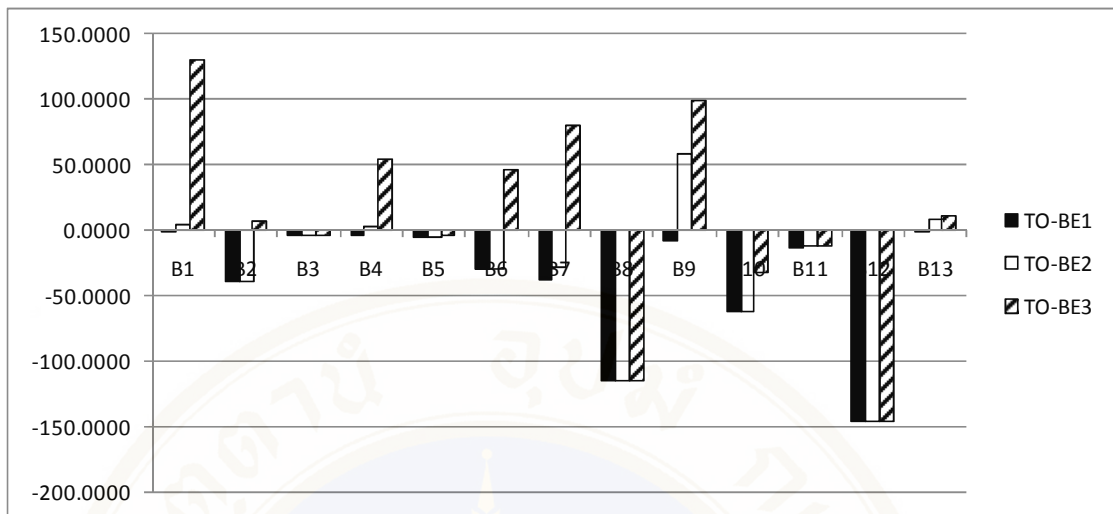


Figure 5.10 Comparison the number of early deliveries of TO-BE with AS-IS at main station 2

From figure 5.10, number of early deliveries is increased by TO-BE 2 and TO-BE 3 of B9 and B13. While number of early deliveries is decreased by TO-BE 1, TO-BE 2 and TO-BE 3 of B3, B5, B8, B10, B11, and B12. TO-BE 1 of B13 lessens the number of early deliveries but TO-BE 2 and TO-BE 3 add the number of early deliveries. TO-BE 3 of B1, B4, B6, and B7 raise the number of early deliveries.

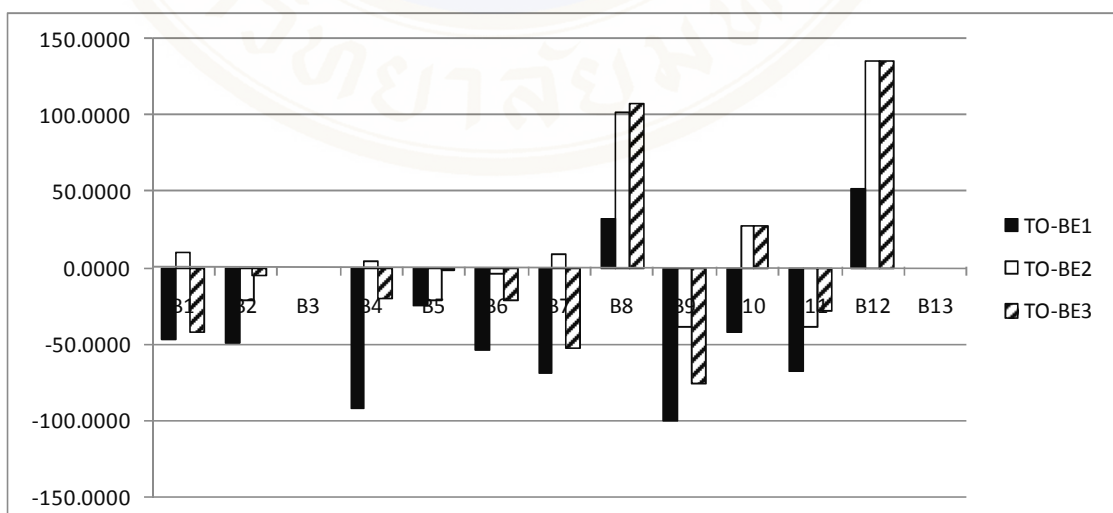


Figure 5.11 Comparison the number of on time deliveries of TO-BE with AS-IS at main station 2

From figure 5.11, TO-BE 1, TO-BE 2 and TO-BE 3 of B8 and B12 increase the number of on time delivery as well as TO-BE 2 of B1, B4, and B7. However TO-BE 1 and TO-BE 3 drop the number of on time delivery. The number of on time is lessened by TO-BE 1, TO-BE 2 and TO-BE 3 of B2, B5, B6, B9, and B11 as same as TO-BE 1 of B10. Nevertheless TO-BE 2 and TO-BE 3 increase the number of on time deliveries. TO-BE1, TO-BE 2 and TO-BE 3 of B3, and B13 do not affect the number of on time deliveries.

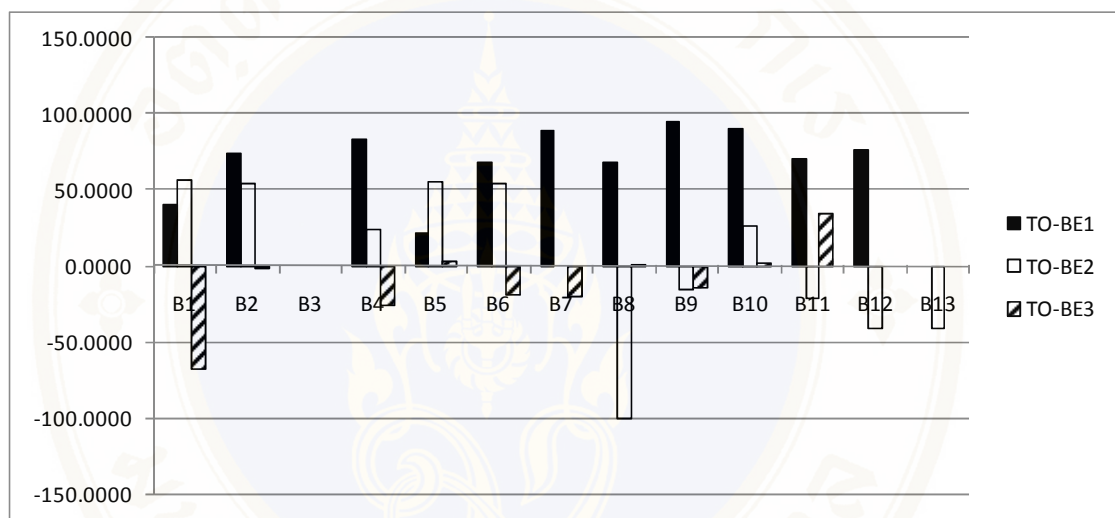


Figure 5.12 Comparison the number of delayed deliveries of TO-BE with AS-IS at main station 2

From figure 5.12, TO-BE 1 increases the number of delayed deliveries. While TO-BE 3 of B1, B2, B4, B6, B7, and B9 decrease the number of delayed deliveries, However TO-BE 1 and TO-BE 2 raise the number of delayed deliveries. Number of delayed deliveries is increased by TO-BE 1, TO-BE 2, and TO-BE 3 of B10, and B11. TO-BE 1, TO-BE 2, and TO-BE 3 of B3, and B13 do not affect the number of delayed deliveries.

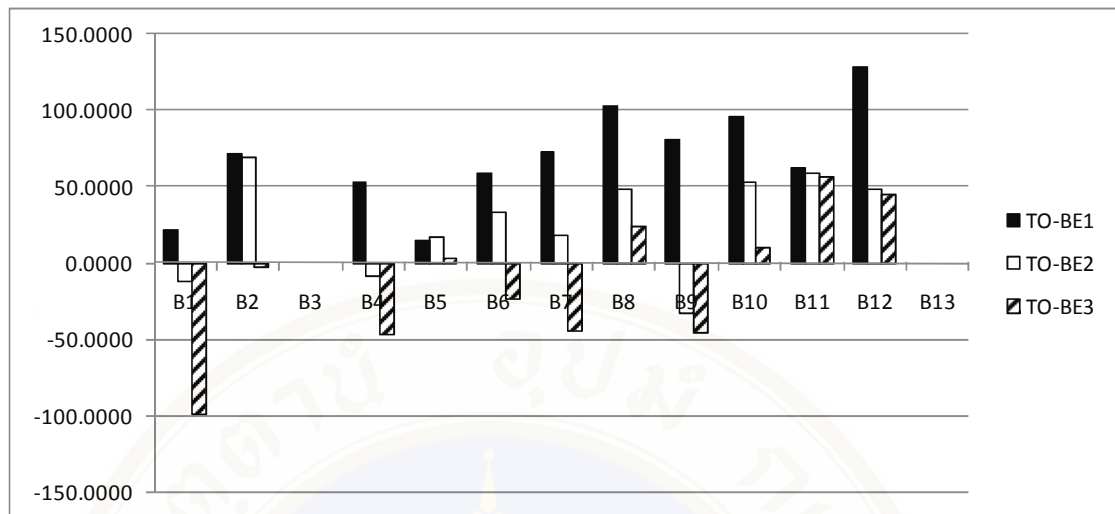


Figure 5.13 Comparison the number of gas shortage times of TO-BE with AS-IS at main station 2

From figure 5.13, TO-BE 1, TO-BE 2, and TO-BE 3 of B8, B10, B11, and B12 escalate the number of gas shortage times. Whereas TO-BE 2 and TO-BE 3 of B1, B4, and B9 decrease the number of gas shortage times as same as TO-BE 3 of B6, and B7. TO-BE 1, TO-BE 2, and TO-BE 3 of B3, and B13 do not affect the number of gas shortage times.

The result of this scenario shows that adjusting reorder point lessens the number of gas shortage times. Some of substations increase the number of gas shortage times especially B5, B8, B10, and B12. The most important issue of natural gas transportation was that gas shortage does not occur at substations. Therefore, the next scenario will consider the number of gas shortage times which should be zero, the number of on time delivery should be increased, the number of delay delivery should be decreased, and the number of early delivery should be decreased respectively. The new reorder point of each substation is shown in table 5.11.

Table 5.11 The new reorder point for each substations of main station 2

Substations	New reorder point (TO-BE4)
B1	Maximum reorder point
B2	Maximum reorder point
B3	Average reorder point
B4	Maximum reorder point
B5	Current reorder point
B6	Maximum reorder point
B7	Maximum reorder point
B8	Current reorder point
B9	Maximum reorder point
B10	Current reorder point
B11	Current reorder point
B12	Current reorder point
B13	Minimum reorder point

The result of the new reorder point each substation by comparing with AS-IS is shown in table 5.12.

Table 5.12 The result of the new reorder point each substation with KPIs at main station 2

KPI	Name in Model	AS-IS	TO-BE4
		Value	Value
Utilization of trailer at main	Utilization of trailer at main2	0.4933	0.4955
Wait time for transport trailer at main	Wait time for transport trailer at main2	677.23	668.49
Number of shortage all sub at main	Number of shortage all sub at main2	382.20	120.77
Shortage time all sub at main	Shortage time all sub at main2	245.89	144.63
Number of early all sub at main	Number of early all sub at main2	690.20	1104.00
Wait time for change trailer all sub at main	Wait time for change trailer all sub at main2	781.19	752.43
On time all sub at main	On time all sub at main2	640.80	418.50
Real Delay all sub at main	Real Delay all sub at main2	198.60	52.33
Order lead time all sub at main	Order lead time all sub at main2	941.81	1015.91

Table 5.12 The result of the new reorder point each substation with KPIs at main station 2 (cont.)

KPI	Name in Model	AS-IS	TO-BE4
		Value	Value
Total delay time all sub at main	Total delay time all sub at main2	209.07	117.39

From Table 5.12, the number of gas shortage times is decreased by TO-BE 4 by 68.40 percent. Decreased average of shortage time all substations equal to 41.18 percent. Decreased average early time delivery of all substations is 3.68 percent. Decreased number of delayed deliveries equal to 73.65 percent, and decreased average order lead time all substation equal to 43.85 percent.

TO-BE 4 increases utilization of trailer when compared with AS-IS because the average waiting time for transport trailer decrease by the new reorder point. The result of each substation is shown in figure 5.14.

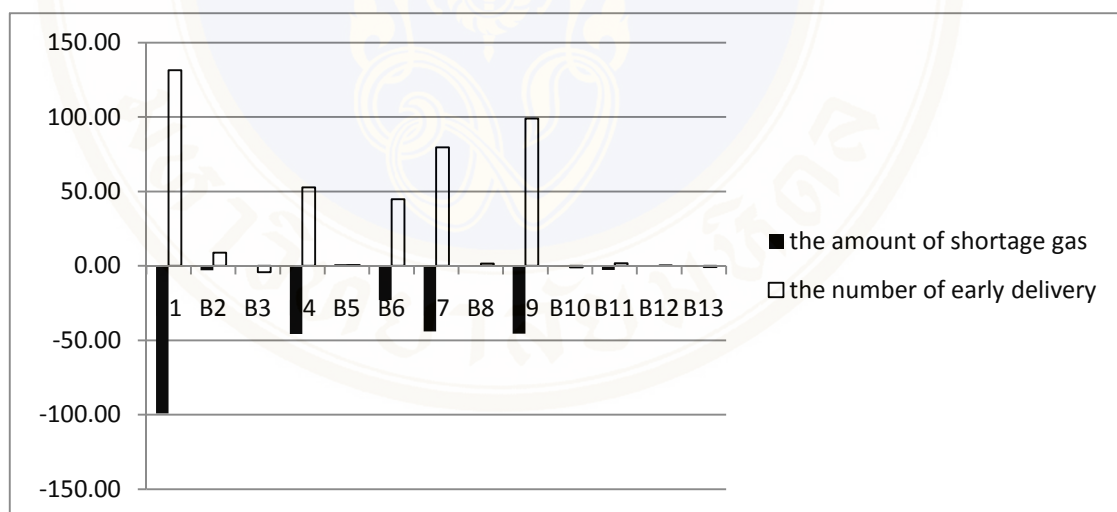


Figure 5.14 Comparison the number of early deliveries and the number of on time deliveries of TO-BE4 with AS-IS at main station 2

From figure 5.14 shows that TO-BE 4 decreases the number of gas shortage times but increases the number of early deliveries. In the next scenarios, it will change the safety stock for reduce the number of gas shortage times as shown in table 5.13.

Table 5.13 Safety stock for each substation of the main station 2

Substation	Safety stock
B1	700
B2	800
B3	500
B4	800
B5	1500
B6	900
B7	700
B8	500
B9	600
B10	700
B11	700
B12	500
B13	500

The result of the new safety stock (TO-BE5) reduces the number of gas shortage times to zero. The number of early deliveries is increased. The result of the new safety stock (TO-BE5) is shown in the table 5.14.

Table 5.14 The result of the new safety stock with KPIs at main station 2

KPI	Name in Model	TO-BE5
		Value
Utilization of trailer at main	Utilization of trailer at main2	0.5167
Wait time for transport trailer at main	Wait time for transport trailer at main2	626.62
Number of shortage all sub at main	Number of shortage all sub at main2	0.233
Shortage time all sub at main	Shortage time all sub at main2	0
Number of early all sub at main	Number of early all sub at main2	1547.00
Wait time for change trailer all sub at main	Wait time for change trailer all sub at main2	557.71
On time all sub at main	On time all sub at main2	58.5
Real Delay all sub at main	Real Delay all sub at main2	0
Order lead time all sub at main	Order lead time all sub at main2	1326.07
Total delay time all sub at main	Total delay time all sub at main2	0

However, utilizations of trailer are poor because there are idle ones. In the next scenario, the numbers of trailer will be adjusted.

5.2.3 Adjust number of trailer

In this scenario, the numbers of trailer will be adjusted using Optquest program. The objective function is to maximize utilizations of trailer. The main constraint is the number of gas shortage times which must be remained the same. The number of trailer of TO-BE5 in main station 2 is shown in the table 5.15.

Table 5.15 The result of number of trailer in TO-BE5 of main station 2

KPI	Name in model	number of trailer			
		50		34	
		Value	Half-Width	Value	Half-Width
Utilization of trailer at main	Utilization of trailer at main1	0.5167	0	0.7599	0
Wait time for transport trailer at main	Wait time for transport trailer at main1	626.62	0.75	193.95	1.19
Number of shortage all sub at main	Number of shortage all sub at main1	0.233	0.01	0.266	0.01
Shortage time all sub at main	Shortage time all sub at main1	0	0	0	0
Real Delay all sub at main	Real Delay all sub at main1	0	0	0	0
Order lead time all sub at main	Order leadtime all sub at main1	1326.07	13.58	1321.06	10.47
Total delay time all sub at main	Total delay time all sub at main1	0	0	0	0

According to table 5.15, the utilization of trailer is increased by 75.99 percent. While the average waiting time for transportation is decreased 69.05 percent. The number of trailer from Optquest is suitable only for the current scenario. Then, the number of trailer at the main station 2 is 37 trailers for safety factor rated at 10%. The next scenario will modify demand to 30 percent and delivery time to 50 percent.

5.2.4 Vary gas demand and delivery time

This scenario will modify demand which changes in between 10-30 percent because the data volume of NGV is moving up amount up to 30 percent per month. And this scenario will modify the delivery time in range of 10-50 percent. The results of TO-BE5 when modified demands and delivery time are shown in figure 5.15.

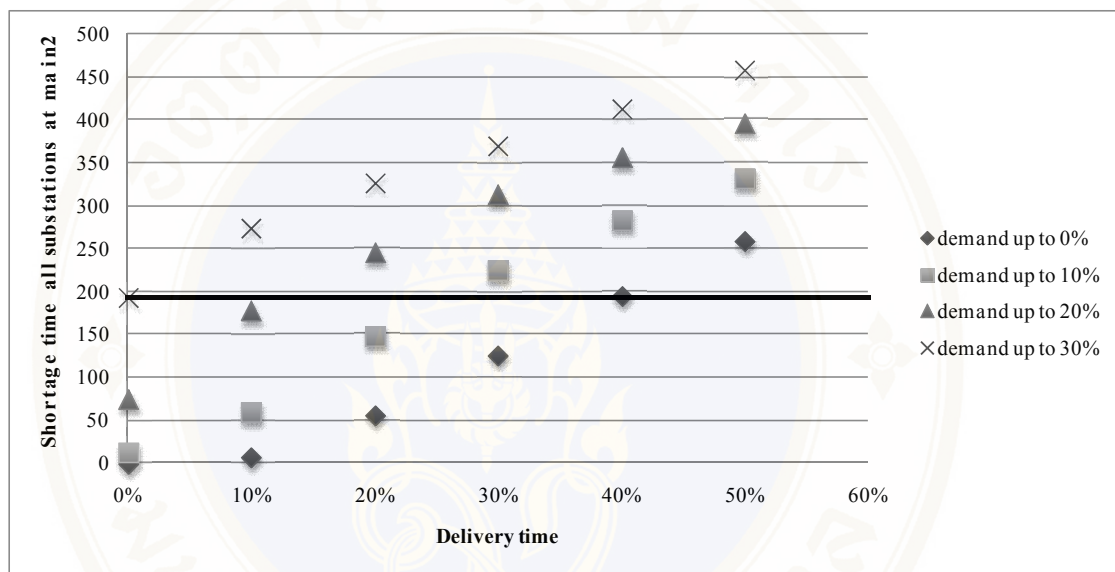


Figure 5.15 The results of TO-BE5 when modified demands and delivery time

From figure 5.15, the black line represents the shortage time all substations at main1 which is 195 minutes. The reorder point from TO-BE4 is acceptable up to 30% of the delivery time or demand increase by 10% and delivery time increase up to 20%. Otherwise demand is increased by 20% or 30% and delivery time is increased by 10%. The main cause of gas shortage occurs at substation B2, B4, B5, and B6 with single trailer. The suggested solution was to calculate the reorder point for new demand and delivery time.

CHAPTER VI

CONCLUSION AND FUTURE DIRECTION

The research found that approximate number of early deliveries is 70% of all delivery at the simulation's current main station1. At main station2 there is approximately 13% of gas shortage and the number of delayed deliveries of all delivery. The adjustment of the reorder point solves these delivery problems. In the main station1, five substations were calculated the reorder point from minimum delivery time. Four substations were calculated from average delivery time. Two substations were calculated from maximum delivery time. Four substations were used the reorder point at 1000 psi. In main station2, one substation was calculated from the minimum and one from average delivery time. Six substations were calculated reorder point from the maximum delivery time. Five substations used reorder point at 1000 psi.

The appropriate reorder point can be determined by the number of trailers placed in each substation. The appropriate reorder point for substation with two trailers is shown in figure 6.1. The appropriate reorder point for substation with one trailer is shown in figure 6.2.

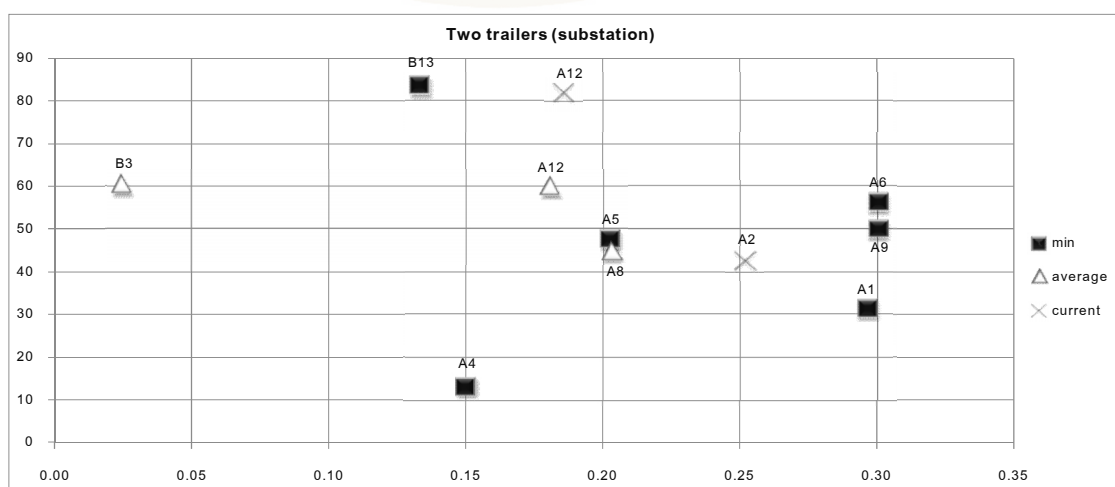


Figure 6.1 The appropriate reorder point for substation with two trailers

From figure 6.1, substations with two trailers is suitable for using the minimum delivery time, and the average delivery time to calculate reorder point or using reorder point at 1000 psi. The substation with two trailers must be careful in terms of early delivery. If reorder point is too much, it can cause early delivery and if reorder point is too low, then it is delay delivery and perhaps gas shortage.

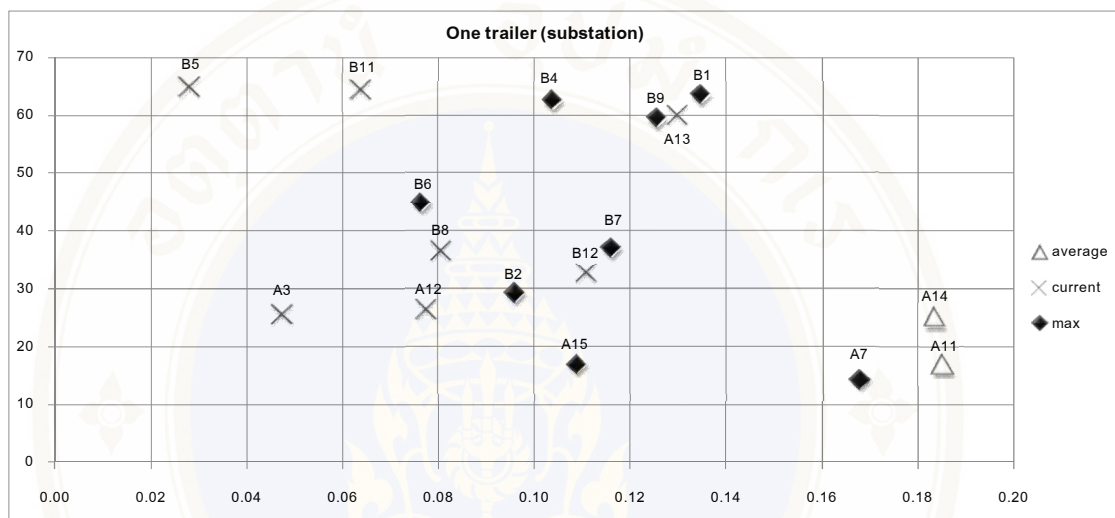


Figure 6.2 The appropriate reorder point for substation with one trailer

From figure 6.2, substation with one trailer is suitable for using the average delivery time, and the maximum delivery time to calculate reorder point or using reorder point at 1000 psi. The substation with one trailer must be treated carefully in the term of gas shortage. If reorder point is too low it might cause delay delivery and gas shortage.

When modify reorder point at main station1, the number of early deliveries reduced and the number of on time delivery increased. In main station2, the number of gas shortage and the number of delay delivery decreased but the number of early deliveries increased. Since 80 % of substations of main station 2 have only one trailer. In practical, the modified reorder point lessened the number of trailer at main station. The main station 1 use only 44 trailers and the main station 2 use only 34 trailers.

Since this research was to modify the reorder point of each substation by simulation. The simulation is used to compare the calculate reorder point by the

number of early deliveries, the number of on time deliveries, the number of delayed time deliveries, and the number of gas shortage times. The simulation shows the advantages and disadvantages of the reorder point. The simulation can modify the variables of demand and delivery time for testing reorder point and the number of trailers. The sensitivity analysis of the reorder point and the number of trailer are modified by two parameters (delivery time and the demand). The calculation reorder point of the main station 1 can support changes of demand and delivery time if they do not exceed 30% increase. The key performance indicator for decision is the average of shortage time all substations must not exceed 225 minutes, or the average of shortage time must not exceed 15 minutes / station. The calculation reorder point of main station 2 appropriates the sum of the changes of demand and delivery time if they do not exceed 30% increase. The reorder point at 1000 psi for main station 2 is not suitable for the changes of demand and delivery time. The key performance indicator for decision is the average of shortage time for all substations must not exceed 195 minutes, or must not exceed 15 minutes / station. In application, main station1 will need to change the calculate reorder point to reorder point at 1000 psi when demand is increased up to 30% and delivery time is increased 40%. Main station 1 must has 48 trailers. Main station 2 must recalculate the reorder when the summation of the increasing demand and delivery time is more than 30%. There are 37 trailers at main station 2.

Future direction

There are many types of NGV trailers. Some substation will be support only type of trailer. Thus, there is problem regarding the plan to contain NGV at the different main station especially the number of trailer contain per round and the type of trailer to contain. Therefore, it necessary to study the type of trailer that should be contained per round, the number of each trailer to be available in the main station, the number of compressors and the bay for the main station. The collected data is used to analyze on delivery requirement for each substation, the compressors maintenance schedule, containing time for each type of trailer, relationship of the bay with the compressor, and the failure of compressor.

REFERENCES

- Aykapop Kongkan (2002). *Vehicle Scheduling For Soft Drink Delivery To Key Account*. Chulalongkorn University.
- Anderson, N. P., Evans, G. W., Biles, W. E., & Whyte, T. C. (2003). *Optimization of a barge transportation system for petroleum delivery*. Paper presented at the Simulation Conference, 2003. Proceedings of the 2003 Winter.
- Chaiwit Tansukkason, Thatree Mathajittiphan, & Peerapat Sitthiyanurak (2007). *Simulation of Cement Bag Distribution: A case study of Siam City Cement Company*. Mahidol University.
- Chen, E. J., Lee, Y. M., & Selikson, P. L. (2002). A simulation study of logistics activities in a chemical plant. *Simulation Modelling Practice and Theory*, 10(3-4), 235-245.
- Cortés, P., Muñuzuri, J., Ibáñez, J. N., & Guadix, J. (2007). Simulation of freight traffic in the Seville inland port. *Simulation Modelling Practice and Theory*, 15(3), 256-271.
- Deborah, B. L., & Morton, O. K. E. (1999). Hub- and-Spoke Network in Air Transportation: An Analytical Review. *Journal of Regional Science*, 39.
- Dogan, C. A., McClain, T. F., & Wicklund, S. A. (1997). Simulation modeling and analysis of a hardwood sawmill. *Simulation Practice and Theory*, 5(5), 387-403.
- Goldsman, D., Pernet, S., & Keebom, K. (2002). *Simulation of transportation logistics*. Paper presented at the Winter Simulation Conference Proceedings
- Kelton, W. D., Sadowski, R. P., & Sturrock, D. T. (2007). *Simulation with Arena* (4 ed.). New York (America): McGraw-Hill.
- Kim, K. H., Seong, Y. R., Kim, T. G., & Park, K. H. (1997). Ordering of simultaneous events in distributed DEVS simulation. *Simulation Practice and Theory*, 5(3), 253-268.

- Kostic, K. (2009). Inventory control as a discrete system control for the fixed-order quantity system. *Applied Mathematical Modelling*, 33(11), 4201-4214.
- Meignan, D., Simonin, O., & Koukam, A. (2007). Simulation and evaluation of urban bus-networks using a multiagent approach. *Simulation Modelling Practice and Theory*, 5(6), 659-671.
- Najibi, H., Rezaei, R., Javanmardi, J., Nasrifar, K., & Moshfeghian, M. (2009). Economic evaluation of natural gas transportation from Iran's South-Pars gas field to market. *Applied Thermal Engineering*, 29(10), 2009-2015.
- NGV FOCUS (2007). Available from:
http://pttweb2.pttplc.com/webngv/Files/pdf/NGV_FOCUS/2008/01/NGV-Station.pdf
- Ottman, W. S., Ford, A. C., & Reinhardt, G. R. (1999). *An aircraft taxi simulation model for the United Parcel Service Louisville Air Park*. Paper presented at the Winter Simulation Conference Proceedings.
- Papier, F., & Thonemann, U. W. (2008). Queuing Models for Sizing and Structuring Rental Fleets. *Transportation Science*, 42(3), 302-317.
- Rizzoli, A. E., Fornara, N., & Gambardella, L. M. (2002). A simulation tool for combined rail/road transport in intermodal terminals. *Mathematics and Computers in Simulation*, 59(1-3), 57-71.
- Wijitar Pumichartpong (2002). *Vehicle Scheduling For Interfacility Delivery of Soft Drinks*. Chalalongkorn University.
- Yang, J., Jaillet, P., & Mahmassani, H. (2002). Real-Time Multivehicle Truckload Pickup and Delivery Problems. *Transportation Science*.
- Zhang, C., & Zhang, C. (2007). Design and simulation of demand information sharing in a supply chain. *Simulation Modelling Practice and Theory*, 15(1), 32-46.
- รุ่งรัตน์ ฤทธิชัย (2003). *คู่มือการสร้างแบบจำลองด้วยโปรแกรม Arena*. Bangkok: SE-EDUCATION Public Company Limited.



APPENDIX A

REDUCTION RATE

A1		A2	
Workday (psi/sec)	Weekend (psi/sec)	Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.15,0.3)	TRIA(0.01,0.22,0.28)	TRIA(0,0.12,0.3)	TRIA(0,0.2,0.29)
TRIA(0,0.24,0.3)	TRIA(0.02,0.14,0.29)	TRIA(0,0.16,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.19,0.3)	TRIA(0.03,0.16,0.29)	TRIA(0,0.12,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.14,0.3)	TRIA(0.04,0.17,0.3)	TRIA(0,0,0.28)	TRIA(0,0.16,0.3)
TRIA(0.02,0.14,0.3)	TRIA(0,0.16,0.28)	TRIA(0,0.15,0.29)	TRIA(0,0.16,0.3)
TRIA(0.02,0.25,0.3)	TRIA(0,0.15,0.26)	TRIA(0,0.12,0.28)	TRIA(0,0.14,0.26)
TRIA(0.03,0.15,0.3)	TRIA(0.01,0.16,0.3)	TRIA(0,0.13,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.16,0.3)	TRIA(0.06,0.14,0.29)	TRIA(0,0.14,0.3)	TRIA(0,0.14,0.27)
TRIA(0,0,0.3)	TRIA(0.02,0.21,0.3)	TRIA(0,0.14,0.29)	TRIA(0,0.14,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.16,0.3)	TRIA(0,0.07,0.3)	TRIA(0,0.15,0.27)
TRIA(0,0,0.3)	TRIA(0,0,0.3)	TRIA(0,0.1,0.3)	TRIA(0,0.16,0.29)
TRIA(0,0,0.3)	TRIA(0,0,0.3)	TRIA(0,0.14,0.3)	TRIA(0,0.13,0.29)
TRIA(0,0,0.3)	TRIA(0,0.18,0.29)	TRIA(0,0.13,0.29)	TRIA(0,0.17,0.23)
TRIA(0,0,0.3)	TRIA(0,0.16,0.3)	TRIA(0,0.15,0.29)	TRIA(0.01,0.16,0.3)
TRIA(0,0,0.3)	TRIA(0.04,0.25,0.29)	TRIA(0,0.14,0.3)	TRIA(0,0.04,0.3)
TRIA(0,0,0.3)	TRIA(0,0.15,0.3)	TRIA(0,0,0.3)	TRIA(0,0.16,0.29)
TRIA(0,0.14,0.3)	TRIA(0.01,0.16,0.3)	TRIA(0,0.1,0.3)	TRIA(0,0.1,0.3)
TRIA(0.02,0.18,0.3)	TRIA(0.02,0.17,0.3)	TRIA(0,0.14,0.3)	TRIA(0,0.14,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.18,0.3)	TRIA(0,0.15,0.29)	TRIA(0,0.18,0.25)
TRIA(0,0.16,0.3)	TRIA(0.04,0.09,0.3)	TRIA(0,0.11,0.3)	TRIA(0,0.14,0.25)
TRIA(0.02,0.2,0.3)	TRIA(0.03,0.27,0.29)	TRIA(0,0.12,0.3)	TRIA(0.03,0.17,0.29)
TRIA(0.01,0.23,0.3)	TRIA(0.01,0.17,0.29)	TRIA(0,0.16,0.28)	TRIA(0,0.16,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.13,0.3)	TRIA(0,0.15,0.29)	TRIA(0.01,0.15,0.29)
TRIA(0,0.16,0.3)	TRIA(0.04,0.16,0.3)	TRIA(0,0.16,0.3)	TRIA(0,0.11,0.28)

A5

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0.02,0.18,0.3)	TRIA(0.01,0.14,0.3)
TRIA(0,0.15,0.3)	TRIA(0,0.12,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.13,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.16,0.28)
TRIA(0,0.12,0.3)	TRIA(0,0.09,0.27)
TRIA(0,0.15,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.15,0.3)	TRIA(0,0.12,0.26)
TRIA(0,0.13,0.3)	TRIA(0,0.18,0.29)
TRIA(0,0.17,0.29)	TRIA(0,0.11,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.15,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.15,0.29)	TRIA(0,0.11,0.24)
TRIA(0,0.16,0.3)	TRIA(0,0.15,0.28)
TRIA(0,0.12,0.3)	TRIA(0,0.18,0.3)
TRIA(0,0.17,0.3)	TRIA(0.01,0.16,0.3)
TRIA(0,0.17,0.3)	TRIA(0.02,0.14,0.28)
TRIA(0,0.16,0.29)	TRIA(0,0.15,0.28)
TRIA(0,0.16,0.3)	TRIA(0,0.18,0.28)
TRIA(0,0.15,0.28)	TRIA(0,0.16,0.26)
TRIA(0,0.15,0.3)	TRIA(0.01,0.12,0.27)
TRIA(0,0.17,0.3)	TRIA(0.03,0.17,0.28)
TRIA(0,0.12,0.3)	TRIA(0,0.18,0.29)
TRIA(0.01,0.16,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.12,0.3)	TRIA(0.03,0.17,0.29)

A6

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0.01,0.15,0.29)	TRIA(0.05,0.15,0.29)
TRIA(0.01,0.13,0.3)	TRIA(0.07,0.14,0.27)
TRIA(0,0.15,0.3)	TRIA(0.04,0.15,0.3)
TRIA(0,0.14,0.3)	TRIA(0.04,0.14,0.3)
TRIA(0,0.15,0.3)	TRIA(0.07,0.14,0.3)
TRIA(0,0.14,0.3)	TRIA(0.06,0.15,0.27)
TRIA(0,0.14,0.3)	TRIA(0.02,0.14,0.27)
TRIA(0,0.15,0.3)	TRIA(0.01,0.14,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.17,0.28)
TRIA(0,0.21,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.12,0.3)	TRIA(0,0.15,0.29)
TRIA(0,0.12,0.3)	TRIA(0,0.17,0.23)
TRIA(0,0.14,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.13,0.29)	TRIA(0.03,0.15,0.3)
TRIA(0,0.17,0.3)	TRIA(0.06,0.13,0.27)
TRIA(0,0.14,0.3)	TRIA(0.04,0.16,0.29)
TRIA(0,0.16,0.3)	TRIA(0.01,0.15,0.29)
TRIA(0.05,0.13,0.28)	TRIA(0.04,0.13,0.26)
TRIA(0,0.15,0.29)	TRIA(0.05,0.13,0.3)
TRIA(0.03,0.15,0.3)	TRIA(0.08,0.16,0.29)
TRIA(0,0.15,0.28)	TRIA(0.07,0.15,0.27)
TRIA(0,0.14,0.3)	TRIA(0.04,0.12,0.29)
TRIA(0.04,0.17,0.3)	TRIA(0.08,0.17,0.3)
TRIA(0.03,0.15,0.29)	TRIA(0.04,0.16,0.3)

A7

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.02,0.27)	TRIA(0,0.01,0.3)
TRIA(0,0.01,0.28)	TRIA(0,0.01,0.27)
TRIA(0,0.01,0.3)	TRIA(0,0.01,0.29)
TRIA(0,0.02,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.01,0.3)	TRIA(0,0.01,0.28)
TRIA(0,0.19,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.19,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.18,0.29)
TRIA(0,0.14,0.3)	TRIA(0,0.19,0.29)
TRIA(0,0.2,0.3)	TRIA(0.01,0.16,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.04,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.07,0.29)
TRIA(0,0.16,0.3)	TRIA(0,0.15,0.3)
TRIA(0,0.17,0.3)	TRIA(0.05,0.14,0.3)
TRIA(0,0.18,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.15,0.29)	TRIA(0,0.15,0.29)
TRIA(0,0.18,0.3)	TRIA(0.01,0.16,0.3)
TRIA(0,0.21,0.3)	TRIA(0,0.17,0.3)
TRIA(0.01,0.18,0.3)	TRIA(0,0.17,0.29)
TRIA(0,0.19,0.3)	TRIA(0,0.16,0.28)
TRIA(0.01,0.15,0.29)	TRIA(0.01,0.17,0.3)
TRIA(0.06,0.17,0.3)	TRIA(0.01,0.16,0.27)
TRIA(0,0.18,0.29)	TRIA(0.01,0.18,0.29)
TRIA(0,0.14,0.3)	TRIA(0,0.03,0.28)

A8

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.15,0.3)	TRIA(0.01,0.21,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.07,0.3)
TRIA(0,0.17,0.3)	TRIA(0.01,0.16,0.29)
TRIA(0,0.14,0.3)	TRIA(0.06,0.14,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.13,0.3)	TRIA(0.01,0.14,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.13,0.3)
TRIA(0,0.2,0.3)	TRIA(0.02,0.17,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.2,0.26)
TRIA(0,0.17,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.15,0.27)
TRIA(0,0.13,0.3)	TRIA(0.04,0.15,0.3)
TRIA(0,0.18,0.3)	TRIA(0.03,0.13,0.29)
TRIA(0,0.21,0.3)	TRIA(0,0.15,0.28)
TRIA(0,0.16,0.3)	TRIA(0.02,0.21,0.3)
TRIA(0,0.14,0.3)	TRIA(0.04,0.19,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.16,0.29)
TRIA(0,0.14,0.3)	TRIA(0.07,0.17,0.29)
TRIA(0.02,0.13,0.3)	TRIA(0.02,0.15,0.28)
TRIA(0,0.18,0.3)	TRIA(0,0.19,0.29)
TRIA(0,0.17,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.17,0.3)	TRIA(0.02,0.11,0.3)

A9

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0.02,0.27,0.3)	TRIA(0.04,0.22,0.29)
TRIA(0,0.25,0.3)	TRIA(0.01,0.25,0.3)
TRIA(0,0.17,0.3)	TRIA(0.08,0.23,0.29)
TRIA(0,0.28,0.3)	TRIA(0.12,0.25,0.3)
TRIA(0,0.22,0.3)	TRIA(0,0.21,0.3)
TRIA(0.04,0.27,0.3)	TRIA(0.14,0.25,0.3)
TRIA(0,0.29,0.3)	TRIA(0.04,0.16,0.3)
TRIA(0.02,0.19,0.3)	TRIA(0.15,0.24,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.22,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.26,0.3)	TRIA(0,0.18,0.3)
TRIA(0,0.28,0.3)	TRIA(0,0.29,0.3)
TRIA(0,0.19,0.3)	TRIA(0,0.23,0.3)
TRIA(0,0.29,0.3)	TRIA(0.08,0.15,0.3)
TRIA(0,0.3,0.3)	TRIA(0.02,0.27,0.3)
TRIA(0,0.27,0.3)	TRIA(0,0.26,0.3)
TRIA(0,0.3,0.3)	TRIA(0.06,0.26,0.29)
TRIA(0.02,0.27,0.3)	TRIA(0.14,0.17,0.3)
TRIA(0,0.24,0.3)	TRIA(0.11,0.28,0.3)
TRIA(0,0.26,0.3)	TRIA(0.12,0.2,0.3)
TRIA(0,0.18,0.3)	TRIA(0.09,0.24,0.3)
TRIA(0.06,0.27,0.3)	TRIA(0.03,0.28,0.3)
TRIA(0,0.19,0.3)	TRIA(0.06,0.23,0.3)
TRIA(0,0.3,0.3)	TRIA(0.05,0.26,0.3)

A10

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.14,0.29)	TRIA(0,0.15,0.28)
TRIA(0,0.14,0.3)	TRIA(0.02,0.19,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.17,0.29)
TRIA(0,0.18,0.29)	TRIA(0,0.16,0.3)
TRIA(0.01,0.14,0.3)	TRIA(0,0.17,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.17,0.29)
TRIA(0,0.14,0.3)	TRIA(0,0.15,0.3)
TRIA(0,0.18,0.3)	TRIA(0.02,0.13,0.29)
TRIA(0,0.17,0.3)	TRIA(0.04,0.18,0.3)
TRIA(0,0.13,0.29)	TRIA(0,0.16,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.17,0.28)
TRIA(0,0.14,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.16,0.3)	TRIA(0.05,0.18,0.3)
TRIA(0,0.15,0.3)	TRIA(0.06,0.2,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.17,0.3)	TRIA(0.02,0.11,0.3)
TRIA(0.01,0.16,0.3)	TRIA(0.02,0.19,0.3)
TRIA(0,0.15,0.3)	TRIA(0.09,0.14,0.25)
TRIA(0.02,0.16,0.3)	TRIA(0.03,0.17,0.3)
TRIA(0,0.16,0.3)	TRIA(0.01,0.16,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.17,0.29)
TRIA(0.04,0.17,0.3)	TRIA(0.02,0.14,0.3)
TRIA(0,0.13,0.3)	TRIA(0.04,0.16,0.3)

A11

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0.01,0.17,0.3)	TRIA(0,0.16,0.29)
TRIA(0.01,0.13,0.3)	TRIA(0.02,0.2,0.3)
TRIA(0,0.02,0.3)	TRIA(0,0.2,0.3)
TRIA(0,0.21,0.3)	TRIA(0.03,0.19,0.28)
TRIA(0,0.16,0.3)	TRIA(0.01,0.16,0.3)
TRIA(0,0.18,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.15,0.29)	TRIA(0.01,0.18,0.3)
TRIA(0,0.19,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.18,0.3)	TRIA(0,0.15,0.29)
TRIA(0,0.17,0.3)	TRIA(0.01,0.16,0.28)
TRIA(0,0.15,0.3)	TRIA(0,0.22,0.29)
TRIA(0,0.14,0.3)	TRIA(0,0.18,0.28)
TRIA(0,0.21,0.3)	TRIA(0,0.16,0.3)
TRIA(0,0.14,0.3)	TRIA(0.01,0.17,0.27)
TRIA(0,0.16,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.17,0.3)	TRIA(0.01,0.01,0.29)
TRIA(0,0.15,0.3)	TRIA(0.01,0.01,0.3)
TRIA(0,0.17,0.3)	TRIA(0.01,0.01,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.01,0.27)
TRIA(0,0.21,0.3)	TRIA(0,0.01,0.28)
TRIA(0,0.17,0.3)	TRIA(0.02,0.28,0.3)
TRIA(0.01,0.14,0.14)	TRIA(0,0.18,0.29)
TRIA(0,0.14,0.3)	TRIA(0.03,0.17,0.3)
TRIA(0.05,0.19,0.3)	TRIA(0.03,0.15,0.27)

A12

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.15,0.25)	TRIA(0.07,0.16,0.24)
TRIA(0,0.13,0.26)	TRIA(0,0.15,0.26)
TRIA(0,0.01,0.26)	TRIA(0,0.01,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.14,0.2)
TRIA(0.01,0.17,0.3)	TRIA(0,0.19,0.29)
TRIA(0.01,0.15,0.3)	TRIA(0,0.18,0.3)
TRIA(0.01,0.15,0.29)	TRIA(0,0.15,0.29)
TRIA(0,0.14,0.27)	TRIA(0.04,0.17,0.27)
TRIA(0,0.17,0.29)	TRIA(0,0.1,0.3)
TRIA(0,0.15,0.29)	TRIA(0,0.13,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0,0.26)
TRIA(0,0.15,0.3)	TRIA(0,0,0.27)
TRIA(0,0.14,0.3)	TRIA(0,0.14,0.28)
TRIA(0,0.15,0.3)	TRIA(0.05,0.14,0.29)
TRIA(0,0.11,0.3)	TRIA(0.03,0.15,0.24)
TRIA(0,0.14,0.29)	TRIA(0.01,0.15,0.25)
TRIA(0.01,0.16,0.3)	TRIA(0.03,0.13,0.28)
TRIA(0.01,0.14,0.3)	TRIA(0.07,0.15,0.25)
TRIA(0.03,0.14,0.27)	TRIA(0.01,0.07,0.28)
TRIA(0,0.08,0.3)	TRIA(0.02,0.21,0.29)
TRIA(0.01,0.17,0.29)	TRIA(0.02,0.17,0.23)
TRIA(0,0.16,0.27)	TRIA(0.03,0.16,0.25)
TRIA(0,0.13,0.26)	TRIA(0,0.16,0.28)
TRIA(0,0.15,0.27)	TRIA(0,0.12,0.25)

A13

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.11,0.29)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0.01,0.3)	TRIA(0,0,0)
TRIA(0,0.16,0.29)	TRIA(0,0.01,0.25)
TRIA(0,0.14,0.3)	TRIA(0,0.17,0.27)
TRIA(0,0.14,0.3)	TRIA(0,0.01,0.28)
TRIA(0,0.15,0.3)	TRIA(0,0.15,0.3)
TRIA(0,0.13,0.3)	TRIA(0.02,0.12,0.3)
TRIA(0,0.15,0.29)	TRIA(0.01,0.15,0.27)
TRIA(0,0.15,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.15,0.3)	TRIA(0.03,0.12,0.29)
TRIA(0,0.13,0.28)	TRIA(0,0.14,0.3)
TRIA(0.01,0.12,0.3)	TRIA(0,0.15,0.29)
TRIA(0,0.15,0.3)	TRIA(0,0.16,0.28)
TRIA(0,0.15,0.3)	TRIA(0.07,0.15,0.26)
TRIA(0,0.16,0.3)	TRIA(0,0.13,0.3)
TRIA(0,0.14,0.3)	TRIA(0,0.15,0.3)
TRIA(0,0.14,0.3)	TRIA(0.02,0.16,0.29)
TRIA(0,0.15,0.29)	TRIA(0.01,0.13,0.28)
TRIA(0,0.15,0.3)	TRIA(0,0.12,0.24)

A14

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.21,0.29)	TRIA(0.02,0.19,0.3)
TRIA(0,0.15,0.29)	TRIA(0.02,0.12,0.29)
TRIA(0,0.12,0.3)	TRIA(0.01,0.14,0.3)
TRIA(0,0.15,0.3)	TRIA(0.02,0.14,0.28)
TRIA(0,0.16,0.3)	TRIA(0.01,0.14,0.29)
TRIA(0.01,0.17,0.3)	TRIA(0,0.18,0.3)
TRIA(0.03,0.14,0.3)	TRIA(0.01,0.17,0.3)
TRIA(0,0.15,0.29)	TRIA(0,0.16,0.29)
TRIA(0,0.14,0.3)	TRIA(0.1,0.15,0.29)
TRIA(0,0.12,0.3)	TRIA(0.01,0.16,0.3)
TRIA(0,0.14,0.29)	TRIA(0,0.16,0.3)
TRIA(0,0.13,0.3)	TRIA(0,0.14,0.29)
TRIA(0,0.2,0.3)	TRIA(0.02,0.15,0.3)
TRIA(0,0.19,0.3)	TRIA(0,0.13,0.3)
TRIA(0,0.14,0.3)	TRIA(0.04,0.17,0.26)
TRIA(0,0.16,0.3)	TRIA(0.06,0.17,0.3)
TRIA(0,0.15,0.3)	TRIA(0.02,0.15,0.3)
TRIA(0.05,0.15,0.29)	TRIA(0.01,0.17,0.3)
TRIA(0.02,0.13,0.3)	TRIA(0.09,0.15,0.28)
TRIA(0,0.14,0.29)	TRIA(0.02,0.15,0.3)
TRIA(0,0.2,0.3)	TRIA(0.02,0.13,0.29)
TRIA(0,0.15,0.28)	TRIA(0.01,0.15,0.29)
TRIA(0.01,0.15,0.29)	TRIA(0.03,0.03,0.29)
TRIA(0,0.18,0.3)	TRIA(0.01,0.14,0.27)

A15

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.11,0.3)	TRIA(0,0.11,0.26)
TRIA(0,0.1,0.24)	TRIA(0,0.06,0.25)
TRIA(0,0.06,0.23)	TRIA(0,0.07,0.29)
TRIA(0,0.09,0.28)	TRIA(0,0.1,0.23)
TRIA(0,0.1,0.27)	TRIA(0,0.07,0.26)
TRIA(0,0.09,0.29)	TRIA(0,0.1,0.28)
TRIA(0,0.09,0.29)	TRIA(0,0.01,0.3)
TRIA(0,0.1,0.29)	TRIA(0,0.1,0.3)
TRIA(0,0.09,0.22)	TRIA(0,0.09,0.29)
TRIA(0,0.09,0.27)	TRIA(0,0.08,0.28)
TRIA(0,0.1,0.26)	TRIA(0,0.12,0.29)
TRIA(0,0.08,0.24)	TRIA(0,0.1,0.28)
TRIA(0,0.08,0.29)	TRIA(0,0.08,0.28)
TRIA(0,0.09,0.29)	TRIA(0.01,0.09,0.27)
TRIA(0,0.1,0.3)	TRIA(0,0.07,0.21)
TRIA(0,0.08,0.3)	TRIA(0,0.08,0.29)
TRIA(0,0.09,0.3)	TRIA(0.01,0.09,0.23)
TRIA(0,0.08,0.27)	TRIA(0.02,0.09,0.26)
TRIA(0,0.08,0.3)	TRIA(0,0.14,0.29)
TRIA(0,0.06,0.29)	TRIA(0,0.1,0.3)
TRIA(0,0.09,0.3)	TRIA(0,0.08,0.25)
TRIA(0,0.09,0.3)	TRIA(0,0.07,0.29)
TRIA(0,0.08,0.28)	TRIA(0,0.08,0.26)
TRIA(0,0.09,0.26)	TRIA(0,0.09,0.29)

B1

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.04,0.3)	TRIA(0,0.02,0.3)
TRIA(0,0.01,0.3)	TRIA(0,0,0)
TRIA(0,0.05,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.21,0.3)
TRIA(0,0.24,0.3)	TRIA(0,0.24,0.3)
TRIA(0,0.18,0.3)	TRIA(0,0.01,0.29)
TRIA(0,0.01,0.3)	TRIA(0,0.18,0.3)
TRIA(0,0.23,0.3)	TRIA(0,0.17,0.3)
TRIA(0,0.23,0.3)	TRIA(0,0.25,0.3)
TRIA(0,0.07,0.3)	TRIA(0,0.02,0.3)
TRIA(0,0.24,0.3)	TRIA(0,0.22,0.3)
TRIA(0,0.17,0.29)	TRIA(0,0.22,0.3)
TRIA(0,0.15,0.3)	TRIA(0,0.02,0.28)
TRIA(0,0.16,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.02,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.3,0.3)
TRIA(0,0.01,0.3)	TRIA(0,0.2,0.28)
TRIA(0,0.01,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.01,0.3)	TRIA(0,0.03,0.3)
TRIA(0,0.21,0.3)	TRIA(0,0.2,0.3)
TRIA(0,0.25,0.3)	TRIA(0,0.05,0.3)
TRIA(0,0.16,0.3)	TRIA(0,0.22,0.29)
TRIA(0,0.13,0.3)	TRIA(0,0.17,0.3)

B2

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.11,0.27)	TRIA(0,0,0)
TRIA(0,0.1,0.27)	TRIA(0,0,0)
TRIA(0,0.12,0.3)	TRIA(0,0,0)
TRIA(0,0.12,0.25)	TRIA(0,0,0)
TRIA(0,0.11,0.3)	TRIA(0,0,0)
TRIA(0,0.12,0.29)	TRIA(0,0,0)
TRIA(0,0.11,0.29)	TRIA(0,0,0)
TRIA(0,0.11,0.26)	TRIA(0,0,0)
TRIA(0,0.12,0.29)	TRIA(0,0,0)
TRIA(0,0.11,0.29)	TRIA(0,0,0)
TRIA(0,0.1,0.3)	TRIA(0,0,0)
TRIA(0,0.13,0.3)	TRIA(0,0,0)
TRIA(0,0.11,0.3)	TRIA(0,0,0)
TRIA(0,0.12,0.29)	TRIA(0,0,0)
TRIA(0,0.11,0.3)	TRIA(0,0,0)
TRIA(0,0.12,0.29)	TRIA(0,0,0)
TRIA(0,0.12,0.28)	TRIA(0,0,0)
TRIA(0,0.11,0.3)	TRIA(0,0,0)
TRIA(0,0.13,0.29)	TRIA(0,0,0)
TRIA(0,0.12,0.3)	TRIA(0,0,0)
TRIA(0,0.13,0.3)	TRIA(0,0,0)
TRIA(0,0.12,0.3)	TRIA(0,0,0)
TRIA(0,0.12,0.3)	TRIA(0,0,0)
TRIA(0.01,0.12,0.3)	TRIA(0,0,0)

B3

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0,0.26)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.26)	TRIA(0,0,0)
TRIA(0,0,0.23)	TRIA(0,0,0)
TRIA(0,0,0.24)	TRIA(0,0,0)
TRIA(0,0,0.21)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.27)	TRIA(0,0,0)
TRIA(0,0,0.26)	TRIA(0,0,0)
TRIA(0,0,0.23)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.28)	TRIA(0,0,0)
TRIA(0,0,0.27)	TRIA(0,0,0)
TRIA(0,0,0.27)	TRIA(0,0,0)
TRIA(0,0,0.26)	TRIA(0,0,0)
TRIA(0,0,0.28)	TRIA(0,0,0)
TRIA(0,0,0.28)	TRIA(0,0,0)
TRIA(0,0,0.18)	TRIA(0,0,0)
TRIA(0,0,0.26)	TRIA(0,0,0)
TRIA(0,0,0.24)	TRIA(0,0,0)
TRIA(0,0,0.24)	TRIA(0,0,0)
TRIA(0,0,0.28)	TRIA(0,0,0)

B4

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.07,0.29)	TRIA(0,0,)
TRIA(0,0.05,0.29)	TRIA(0,0,)
TRIA(0,0.02,0.26)	TRIA(0,0,)
TRIA(0,0.02,0.28)	TRIA(0,0.17,)
TRIA(0,0.1,0.3)	TRIA(0,0.12,)
TRIA(0,0.1,0.26)	TRIA(0.01,0.06,)
TRIA(0,0.14,0.3)	TRIA(0,0.14,)
TRIA(0,0.05,0.29)	TRIA(0,0.14,)
TRIA(0,0.1,0.29)	TRIA(0,0.13,)
TRIA(0,0.14,0.3)	TRIA(0,0.16,)
TRIA(0,0.1,0.3)	TRIA(0,0.11,)
TRIA(0,0.13,0.3)	TRIA(0,0.19,)
TRIA(0,0.14,0.3)	TRIA(0,0.16,)
TRIA(0,0.1,0.3)	TRIA(0,0.15,)
TRIA(0,0.1,0.3)	TRIA(0,0.14,)
TRIA(0,0.14,0.3)	TRIA(0,0.14,)
TRIA(0,0.12,0.28)	TRIA(0,0.14,)
TRIA(0,0.15,0.28)	TRIA(0,0.09,)
TRIA(0,0.14,0.3)	TRIA(0,0.09,)
TRIA(0,0.15,0.3)	TRIA(0,0.13,)
TRIA(0,0.14,0.3)	TRIA(0,0.18,)
TRIA(0,0.16,0.3)	TRIA(0,0.11,)
TRIA(0,0.15,0.29)	TRIA(0,0.15,)
TRIA(0,0.1,0.28)	TRIA(0,0.05,)

B5

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0,0.25)	TRIA(0,0,0)
TRIA(0,0,0.25)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.28)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.28)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.23)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.29)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.3)	TRIA(0,0,0)
TRIA(0,0,0.27)	TRIA(0,0,0)

B6

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.08,0.28)	TRIA(0,0.09,0.12)
TRIA(0,0.08,0.25)	TRIA(0,0.08,0.13)
TRIA(0,0.08,0.22)	TRIA(0,0.09,0.25)
TRIA(0,0.09,0.17)	TRIA(0,0.07,0.19)
TRIA(0,0.09,0.29)	TRIA(0,0.09,0.22)
TRIA(0,0.09,0.22)	TRIA(0,0.11,0.26)
TRIA(0,0.08,0.29)	TRIA(0,0.01,0.2)
TRIA(0,0.11,0.22)	TRIA(0,0.01,0.18)
TRIA(0,0.08,0.27)	TRIA(0,0.01,0.29)
TRIA(0,0.09,0.26)	TRIA(0,0.1,0.26)
TRIA(0,0.08,0.23)	TRIA(0,0.08,0.17)
TRIA(0,0.09,0.29)	TRIA(0,0.09,0.16)
TRIA(0,0.08,0.26)	TRIA(0,0.09,0.15)
TRIA(0,0.08,0.26)	TRIA(0,0.09,0.19)
TRIA(0,0.08,0.29)	TRIA(0.04,0.07,0.28)
TRIA(0,0.08,0.22)	TRIA(0,0.09,0.15)
TRIA(0,0.08,0.3)	TRIA(0,0.08,0.28)
TRIA(0,0.09,0.29)	TRIA(0,0.08,0.24)
TRIA(0,0.09,0.24)	TRIA(0,0.09,0.25)
TRIA(0,0.09,0.29)	TRIA(0,0.08,0.28)
TRIA(0,0.09,0.28)	TRIA(0,0.12,0.22)
TRIA(0,0.08,0.29)	TRIA(0,0.1,0.28)
TRIA(0,0.09,0.26)	TRIA(0,0.1,0.21)
TRIA(0,0.08,0.27)	TRIA(0,0.09,0.2)

B7

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.1,0.28)	TRIA(0,0.07,0.29)
TRIA(0,0.12,0.3)	TRIA(0,0.05,0.3)
TRIA(0,0.14,0.29)	TRIA(0,0.17,0.27)
TRIA(0,0.11,0.24)	TRIA(0,0.13,0.22)
TRIA(0,0.1,0.3)	TRIA(0,0.14,0.28)
TRIA(0,0.11,0.28)	TRIA(0,0.12,0.23)
TRIA(0,0.11,0.29)	TRIA(0,0.1,0.18)
TRIA(0,0.11,0.29)	TRIA(0,0.1,0.27)
TRIA(0,0.12,0.3)	TRIA(0,0.1,0.29)
TRIA(0,0.11,0.3)	TRIA(0,0.18,0.29)
TRIA(0,0.1,0.3)	TRIA(0.03,0.13,0.21)
TRIA(0,0.11,0.27)	TRIA(0,0.12,0.27)
TRIA(0,0.1,0.3)	TRIA(0,0.1,0.2)
TRIA(0,0.11,0.28)	TRIA(0,0.11,0.15)
TRIA(0,0.11,0.3)	TRIA(0,0.09,0.3)
TRIA(0,0.09,0.3)	TRIA(0,0.18,0.25)
TRIA(0,0.12,0.29)	TRIA(0.09,0.15,0.18)
TRIA(0,0.12,0.29)	TRIA(0.07,0.12,0.15)
TRIA(0,0.1,0.29)	TRIA(0.08,0.1,0.14)
TRIA(0,0.13,0.3)	TRIA(0,0.1,0.25)
TRIA(0,0.11,0.28)	TRIA(0,0.17,0.29)
TRIA(0,0.11,0.3)	TRIA(0.05,0.14,0.29)
TRIA(0,0.12,0.27)	TRIA(0.07,0.12,0.2)
TRIA(0,0.12,0.3)	TRIA(0.06,0.12,0.17)

B8

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.07,0.20)	TRIA(0,0.07,0.15)
TRIA(0,0.07,0.30)	TRIA(0,0.08,0.18)
TRIA(0,0.09,0.29)	TRIA(0,0.07,0.12)
TRIA(0,0.11,0.26)	TRIA(0,0.07,0.25)
TRIA(0,0.08,0.21)	TRIA(0,0.07,0.19)
TRIA(0,0.07,0.16)	TRIA(0,0.07,0.27)
TRIA(0,0.07,0.14)	TRIA(0,0.07,0.24)
TRIA(0,0.06,0.25)	TRIA(0,0.08,0.22)
TRIA(0,0.07,0.28)	TRIA(0,0.06,0.24)
TRIA(0,0.07,0.29)	TRIA(0,0.06,0.22)
TRIA(0,0.07,0.30)	TRIA(0,0.07,0.21)
TRIA(0,0.08,0.28)	TRIA(0,0.08,0.16)
TRIA(0,0.08,0.30)	TRIA(0,0.07,0.16)
TRIA(0,0.08,0.13)	TRIA(0,0.08,0.18)
TRIA(0,0.07,0.26)	TRIA(0,0.07,0.26)
TRIA(0,0.07,0.28)	TRIA(0,0.06,0.28)
TRIA(0,0.07,0.23)	TRIA(0,0.06,0.18)
TRIA(0,0.07,0.27)	TRIA(0,0.09,0.26)
TRIA(0,0.07,0.28)	TRIA(0,0.09,0.22)
TRIA(0,0.07,0.30)	TRIA(0,0.08,0.25)
TRIA(0,0.09,0.29)	TRIA(0,0.08,0.18)
TRIA(0,0.08,0.25)	TRIA(0,0.07,0.28)
TRIA(0,0.07,0.17)	TRIA(0,0.07,0.20)
TRIA(0,0.07,0.28)	TRIA(0,0.07,0.23)

B9

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.11,0.3)	TRIA(0.02,0.13,0.29)
TRIA(0,0.12,0.3)	TRIA(0.06,0.12,0.28)
TRIA(0,0.12,0.3)	TRIA(0.04,0.13,0.29)
TRIA(0,0.11,0.3)	TRIA(0.02,0.11,0.29)
TRIA(0,0.11,0.3)	TRIA(0.07,0.12,0.3)
TRIA(0,0.11,0.29)	TRIA(0,0.12,0.26)
TRIA(0,0.12,0.29)	TRIA(0.02,0.12,0.29)
TRIA(0,0.12,0.27)	TRIA(0,0.13,0.28)
TRIA(0,0.12,0.26)	TRIA(0,0.11,0.19)
TRIA(0,0.12,0.29)	TRIA(0,0.11,0.28)
TRIA(0,0.11,0.3)	TRIA(0,0.11,0.27)
TRIA(0,0.13,0.3)	TRIA(0,0.12,0.29)
TRIA(0,0.12,0.29)	TRIA(0,0.1,0.29)
TRIA(0,0.12,0.3)	TRIA(0.02,0.12,0.27)
TRIA(0,0.12,0.29)	TRIA(0.06,0.12,0.29)
TRIA(0,0.11,0.3)	TRIA(0,0.12,0.26)
TRIA(0,0.12,0.3)	TRIA(0,0.11,0.3)
TRIA(0,0.11,0.27)	TRIA(0,0.12,0.28)
TRIA(0,0.11,0.28)	TRIA(0,0.13,0.27)
TRIA(0,0.12,0.3)	TRIA(0.04,0.12,0.3)
TRIA(0,0.11,0.3)	TRIA(0.04,0.13,0.25)
TRIA(0,0.13,0.3)	TRIA(0,0.12,0.28)
TRIA(0,0.1,0.29)	TRIA(0,0.12,0.29)
TRIA(0.04,0.11,0.3)	TRIA(0,0.11,0.28)

B10

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.08,0.26)	TRIA(0,0.09,0.3)
TRIA(0,0.07,0.3)	TRIA(0.02,0.08,0.21)
TRIA(0,0.08,0.29)	TRIA(0,0.07,0.14)
TRIA(0,0.08,0.24)	TRIA(0,0.07,0.23)
TRIA(0,0.08,0.22)	TRIA(0,0.06,0.22)
TRIA(0,0.08,0.2)	TRIA(0,0.07,0.19)
TRIA(0,0.07,0.29)	TRIA(0,0.05,0.27)
TRIA(0,0.07,0.2)	TRIA(0,0.04,0.17)
TRIA(0,0.06,0.23)	TRIA(0,0.04,0.17)
TRIA(0,0.08,0.3)	TRIA(0,0.04,0.27)
TRIA(0,0.08,0.23)	TRIA(0,0.03,0.16)
TRIA(0,0.07,0.29)	TRIA(0,0.03,0.22)
TRIA(0,0.08,0.29)	TRIA(0,0.07,0.16)
TRIA(0,0.07,0.26)	TRIA(0,0.08,0.24)
TRIA(0,0.07,0.22)	TRIA(0,0.07,0.27)
TRIA(0,0.08,0.24)	TRIA(0,0.08,0.28)
TRIA(0,0.08,0.3)	TRIA(0,0.08,0.19)
TRIA(0,0.08,0.3)	TRIA(0,0.09,0.27)
TRIA(0,0.06,0.28)	TRIA(0.03,0.09,0.2)
TRIA(0,0.09,0.29)	TRIA(0.03,0.06,0.3)
TRIA(0,0.09,0.2)	TRIA(0,0.04,0.24)
TRIA(0,0.07,0.25)	TRIA(0,0.04,0.17)
TRIA(0,0.08,0.24)	TRIA(0.01,0.03,0.22)
TRIA(0,0.08,0.27)	TRIA(0,0.04,0.23)

B11

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0,0)
TRIA(0,0,0)	TRIA(0,0.01,0.26)
TRIA(0,0.09,0.29)	TRIA(0,0.09,0.22)
TRIA(0,0.09,0.22)	TRIA(0,0.1,0.3)
TRIA(0,0.08,0.28)	TRIA(0,0.09,0.16)
TRIA(0,0.08,0.28)	TRIA(0,0.08,0.15)
TRIA(0,0.08,0.3)	TRIA(0,0.07,0.12)
TRIA(0,0.07,0.29)	TRIA(0,0.07,0.11)
TRIA(0,0.07,0.3)	TRIA(0,0.08,0.13)
TRIA(0,0.07,0.3)	TRIA(0,0.07,0.18)
TRIA(0,0.08,0.3)	TRIA(0,0.08,0.16)
TRIA(0,0.08,0.26)	TRIA(0,0.07,0.29)
TRIA(0,0.09,0.3)	TRIA(0,0.07,0.28)
TRIA(0,0.09,0.2)	TRIA(0,0.08,0.16)
TRIA(0,0.07,0.3)	TRIA(0,0.08,0.28)
TRIA(0,0.08,0.21)	TRIA(0,0.08,0.21)
TRIA(0,0.07,0.3)	TRIA(0,0.09,0.17)
TRIA(0,0.08,0.26)	TRIA(0,0.07,0.19)
TRIA(0,0.01,0.22)	TRIA(0,0.01,0.22)
TRIA(0,0,0)	TRIA(0,0,0)

B12

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.12,0.28)	TRIA(0,0.12,0.3)
TRIA(0,0.12,0.3)	TRIA(0,0.09,0.28)
TRIA(0,0.11,0.3)	TRIA(0,0.12,0.3)
TRIA(0,0.13,0.29)	TRIA(0,0.1,0.28)
TRIA(0,0.1,0.28)	TRIA(0,0.09,0.29)
TRIA(0,0.12,0.28)	TRIA(0,0.14,0.3)
TRIA(0,0.1,0.3)	TRIA(0,0.11,0.28)
TRIA(0,0.1,0.29)	TRIA(0,0.1,0.28)
TRIA(0,0.11,0.3)	TRIA(0,0.1,0.29)
TRIA(0,0.1,0.27)	TRIA(0,0.1,0.24)
TRIA(0,0.08,0.3)	TRIA(0,0.1,0.28)
TRIA(0,0.11,0.3)	TRIA(0,0.12,0.26)
TRIA(0,0.08,0.29)	TRIA(0,0.1,0.25)
TRIA(0,0.1,0.28)	TRIA(0,0.1,0.28)
TRIA(0,0.1,0.26)	TRIA(0,0.08,0.29)
TRIA(0,0.1,0.29)	TRIA(0,0.11,0.25)
TRIA(0,0.1,0.3)	TRIA(0,0.11,0.21)
TRIA(0,0.09,0.29)	TRIA(0,0.11,0.26)
TRIA(0,0.11,0.28)	TRIA(0,0.11,0.28)
TRIA(0,0.11,0.3)	TRIA(0,0.1,0.29)
TRIA(0,0.11,0.28)	TRIA(0,0.14,0.22)
TRIA(0,0.11,0.28)	TRIA(0,0.13,0.3)
TRIA(0,0.12,0.3)	TRIA(0,0.09,0.23)
TRIA(0,0.09,0.28)	TRIA(0,0.13,0.28)

B13

Workday (psi/sec)	Weekend (psi/sec)
TRIA(0,0.21,0.3)	TRIA(0,0,0)
TRIA(0,0.23,0.29)	TRIA(0,0.01,0.3)
TRIA(0,0.22,0.29)	TRIA(0,0.22,0.3)
TRIA(0,0.24,0.3)	TRIA(0,0.25,0.3)
TRIA(0,0.08,0.3)	TRIA(0,0.01,0.3)
TRIA(0,0.13,0.3)	TRIA(0,0,0)
TRIA(0,0.21,0.3)	TRIA(0,0.01,0.28)
TRIA(0,0.23,0.3)	TRIA(0,0.01,0)
TRIA(0,0.22,0.29)	TRIA(0,0.05,0.3)
TRIA(0,0.17,0.3)	TRIA(0,0.22,0.28)
TRIA(0,0.2,0.29)	TRIA(0,0.26,0.3)
TRIA(0,0.22,0.3)	TRIA(0,0.23,0.29)
TRIA(0,0.23,0.3)	TRIA(0,0.29,0.3)
TRIA(0,0.18,0.3)	TRIA(0,0.21,0.3)
TRIA(0,0.27,0.3)	TRIA(0,0.2,0.3)
TRIA(0,0.13,0.3)	TRIA(0,0.14,0.3)
TRIA(0,0.25,0.3)	TRIA(0,0.08,0.29)
TRIA(0,0.2,0.28)	TRIA(0,0.12,0.3)
TRIA(0,0.25,0.29)	TRIA(0,0.16,0.29)
TRIA(0,0.17,0.3)	TRIA(0.01,0.01,0.3)
TRIA(0,0.24,0.3)	TRIA(0,0.2,0.3)
TRIA(0,0.02,0.3)	TRIA(0,0.23,0.3)
TRIA(0,0.22,0.3)	TRIA(0,0.25,0.3)
TRIA(0,0.26,0.28)	TRIA(0,0,0)

APPENDIX B

RESULT FOR 185 REPLICATIONS

The result of 185 replications

KPI	Average value	Half Width	Expected Half Width (Average*0.05)	Number of replication
Utilization of trailer at main1	0.5208	.00	0.02608	185
Wait time for transport trailer at main1	645.02	.10	32.251	185
Shortage times1	0	<.00	0	185
Shortage times10	0	<.00	0	185
Shortage times11	0	<.00	0	185
Shortage times12	0	<.00	0	185
shortage times13	0	<.00	0	185
Shortage times14	0	<.00	0	185
shortage times15	0	<.00	0	185
Shortage times2	0	<.00	0	185
shortage times3	0	<.00	0	185
Shortage times4	0	<.00	0	185
Shortage times5	0	<.00	0	185
Shortage times6	0	<.00	0	185
Shortage times7	0	<.00	0	185
Shortage times8	0	<.00	0	185
Shortage times9	0	<.00	0	185
Number of shortage all sub at main1	0	<.00	0.40108	185

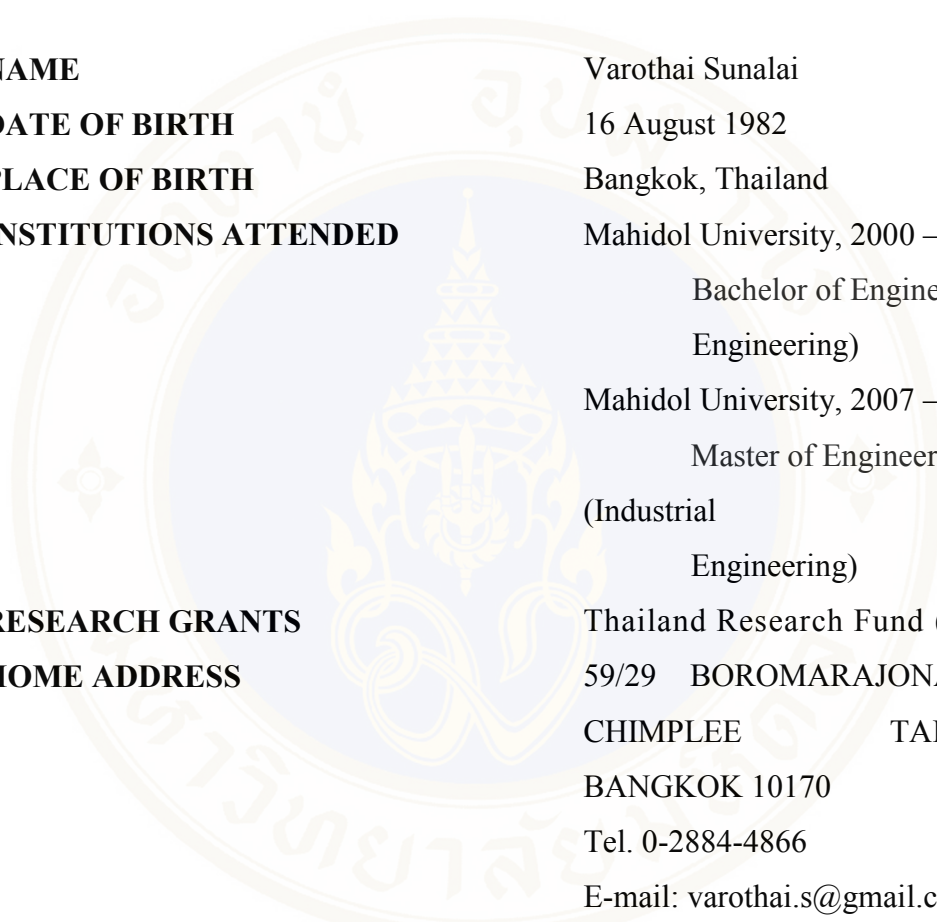
KPI	Average value	Half Width	Expected Half Width (Average*0.05)	Number of replication
Record shortage time7	0	<.00	0	185
Shortage time all sub at main1	0	<.00	0	185
early1	96.0162	< 1.04	4.80081	185
early10	0	< .00	0	185
early11	169.5	<.10	8.475	185
early12	147	<.01	7.35	185
early13	14.8054	<.19	0.74027	185
early14	172	<.00	8.6	185
early15	102	<.02	5.1	185
early2	27.6649	<.67	1.383245	185
early3	58.5135	<.07	2.925675	185
early4	148.58	<.08	7.429	185
early5	160.18	<.06	8.009	185
early6	161.14	<.07	8.057	185
early7	103.21	<.04	5.1605	185
early8	0	<.00	0	185
early9	198.64	<.08	9.932	185
Number of early all sub at main1	1559.25	1.33	77.9625	185
Wait time for change trailer at sub1	9.1923	.08	0.459615	185
Wait time for change trailer at sub10	0	.00	0	185

KPI	Average value	Half Width	Expected Half Width (Average*0.05)	Number of replication
Wait time for change trailer at sub11	14.4045	.05	0.720225	185
Wait time for change trailer at sub12	0.00110315	.03	5.51575E-05	185
Wait time for change trailer at sub13	60.1972	1.69	3.00986	185
Wait time for change trailer at sub14	7.7539	.01	0.387695	185
Wait time for change trailer at sub15	35.3668	.92	1.76834	185
Wait time for change trailer at sub2	7.6413	.17	0.382065	185
Wait time for change trailer at sub3	57.8225	1.13	2.891125	185
Wait time for change trailer at sub4	46.8416	.08	2.34208	185
Wait time for change trailer at sub5	3.6437	.24	0.182185	185
Wait time for change trailer at sub6	10.2655	.33	0.513275	185
Wait time for change trailer at sub7	13.4101	.05	0.670505	185
Wait time for change trailer at sub8	0	.00	0	185
Wait time for change trailer at sub9	7.4223	.27	0.371115	185
Wait time for change trailer all sub at main1	273.96	2.12	13.698	185

KPI	Average value	Half Width	Expected Half Width (Average*0.05)	Number of replication
ontime1	81.6919	<1.00	4.084595	185
ontime10	0.7514	<.12	0.03757	185
ontime11	0.5459	<.10	0.027295	185
ontime12	0	<.00	0	185
ontime13	113.22	<.19	5.661	185
ontime14	0	<.00	0	185
ontime15	0	<.00	0	185
ontime2	114.42	<.88	5.721	185
ontime3	0	<.00	0	185
ontime4	0	<.00	0	185
ontime5	0	<.00	0	185
ontime6	0	<.00	0	185
ontime7	0	<.00	0	185
ontime8	165	<.00	8.25	185
ontime9	0	<.00	0	185
Real late 1	0.1946	<.07	0.00973	185
Real late 10	158.25	<.12	7.9485	185
Real late 11	0	<.00	0	185
Real late 12	0	<.00	0	185
Real late 13	0	<.00	0	185
Real late 14	0	<.00	0	185
Real late 15	0	<.00	0	185
Real late 2	26.0757	<.64	1.303785	185

KPI	Average value	Half Width	Expected Half Width (Average*0.05)	Number of replication
Real late 3	0	< .00	0	185
Real late 4	0	< .00	0	185
Real late 5	0	< .00	0	185
Real late 6	0	< .00	0	185
Real late 7	0	< .00	0	185
Real late 8	0	< .00	0	185
Real late 9	0	< .00	0	185
Real late all sub at main1	184.52	.65	9.226	185
order leadtime1	33.9259	<.05	1.69727	185
order leadtime10	60	<.00	3	185
order leadtime11	33.2249	<.01	1.661245	185
order leadtime12	82.1266	<.14	4.10633	185
order leadtime13	56.9961	<.14	2.849805	185
order leadtime14	32.7539	<.01	1.637695	185
order leadtime15	52.7134	<.91	2.63567	185
order leadtime2	43.1801	<.1	2.159005	185
order leadtime3	85.8581	<1.12	4.292905	185
order leadtime4	37.7593	<.02	1.887965	185
order leadtime5	48.1914	<.11	2.40957	185
order leadtime6	56.7061	<.18	2.835305	185
order leadtime7	39.075	<.03	1.95375	185
order leadtime8	45	<.00	2.25	185
order leadtime9	42.9849	<.09	2.149245	185

KPI	Average value	Half Width	Expected Half Width (Average*0.05)	Number of replication
Order leadtime all sub at main1	750.52	1.46	37.526	185
late time1	0.1739	<.08	0.008695	185
late time10	5.5436	<.01	0.27718	185
late time2	5.5863	<.12	0.279315	185

BIOGRAPHY

NAME	Varothai Sunalai
DATE OF BIRTH	16 August 1982
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Mahidol University, 2000 – 2005 Bachelor of Engineering (Civil Engineering) Mahidol University, 2007 – 2010 Master of Engineering (Industrial Engineering)
RESEARCH GRANTS	Thailand Research Fund (TRF)
HOME ADDRESS	59/29 BOROMARAJONANI ROAD CHIMPLEE TALINGCHAN BANGKOK 10170 Tel. 0-2884-4866 E-mail: varothai.s@gmail.com
PUBLICATION/PRESENTATION	Technology and Innovation for Sustainable Development International Conference (TISD 2010) Faculty of Engineering, Khon Kean University, Thailand